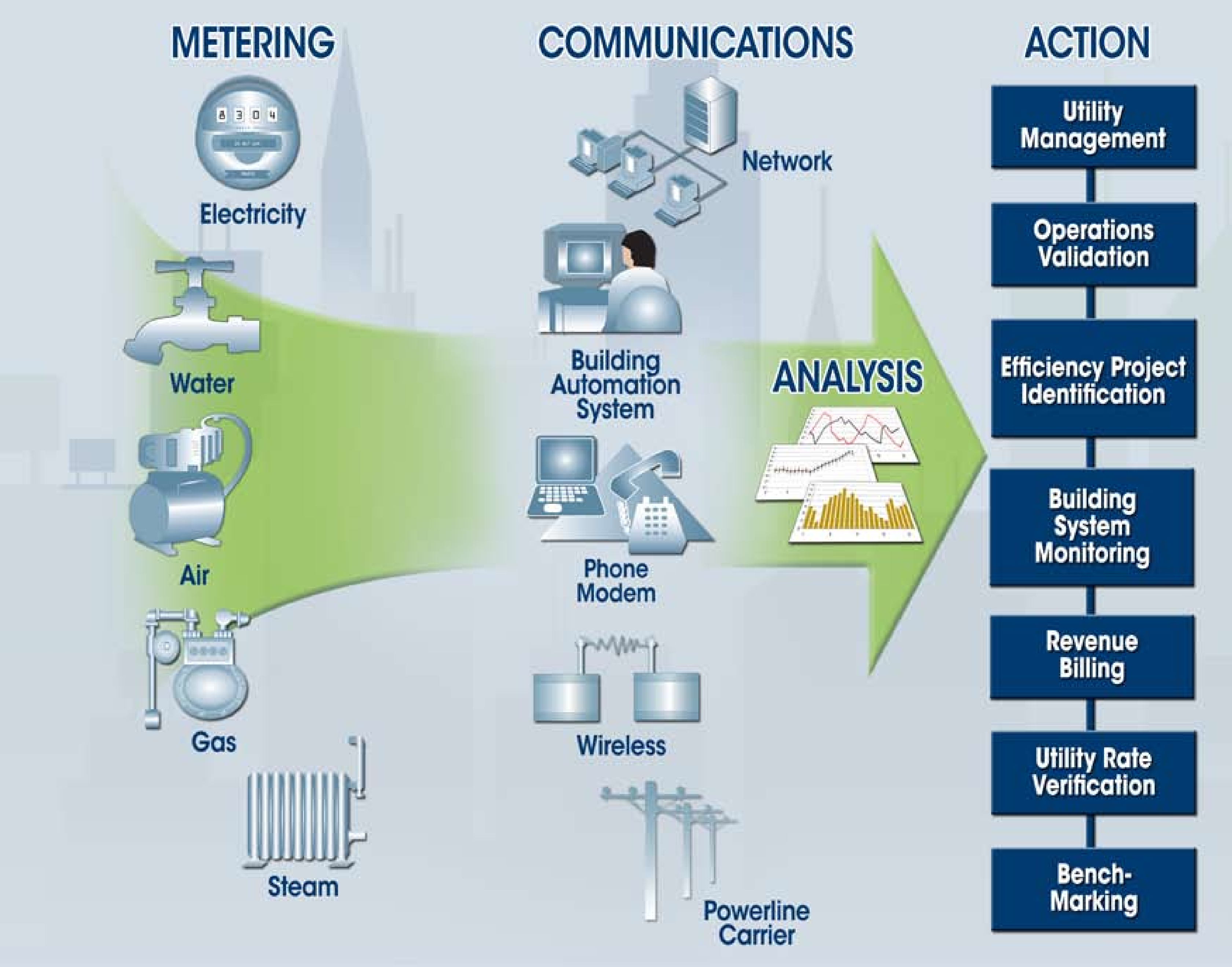
Metering Best Practices

A Guide to Achieving **Utility Resource Efficiency**

October 2007



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Metering

Best Practices

A Guide to Achieving Utility Resource Efficiency

G. P. Sullivan
R. Pugh
W. D. Hunt

October 2007

Prepared by
Pacific Northwest National Laboratory
for the Federal Energy Management Program
U.S. Department of Energy

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Preface

This Metering Best Practices Guide was developed under the direction of the U.S. Department of Energy's Federal Energy Management Program (FEMP). The mission of FEMP is to reduce the cost and environmental impact of the federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at federal sites. Each of these activities is directly related to achieving requirements set forth in the *Energy Policy Acts of 1992 and 2005* and the goals that have been established in Executive Orders 13123 and 13423 – but also those practices that are inherent in sound management of federal financial and personnel resources.

The focus of this guide is to provide the Federal Energy/ Facility manager and practitioner with information and actions aimed at understanding metering and working to achieve the potential savings and benefits.

The learning objectives of this guide are as follows:

- Highlight the numerous benefits to metering including those driving the EPAct legislation as well those used in making the business case for metering.
- Describe the methods and approaches for building-level, panel-level, and end-use metering.
- Achieve an understanding of metering technologies, equipment, and applications.
- Explain the different data communication options for metered data.
- Understand and be able to outline the key elements of a metering plan.
- Highlight the different options for financing metering programs.
- Provide descriptions of applications for meters, data, and data analysis.
- Describe with case studies some immediate metering ideas to generate energy and cost savings.

The focus of this guide is to provide the Federal Energy/Facility manager and practitioner with information and actions aimed at understanding metering and working to achieve the potential savings and benefits.

The guide consists of nine chapters. The first chapter is an introduction and an overview. Chapter 2 provides the rationale for "Why Metering?" Chapter 3 discusses metering planning, providing key issues and highlighting their importance. Chapter 4 examines metering approaches and their role in an overall metering program. Chapter 5 looks at the different metering technologies by major utility type: electricity, natural gas, steam, potable water, and high-temperature/chilled water. Chapter 6 focuses on metering communications and data storage. Chapter 7 describes the various uses for metered data and options on data analysis via energy information systems. Chapter 8 covers the topic of metering economics and the different options for financing metering in the federal sector. Chapter 9 finishes the guide with some federal-sector case studies and success stories. Additional information is provided in the appendixes.

Acknowledgments

This guide is the result of numerous people working to achieve a common goal of highlighting the importance of metering and the resulting opportunities for energy efficiency across the federal sector. The authors wish to acknowledge the contribution and valuable assistance provided by the staff of the Federal Energy Management Program (FEMP). Specifically, we would like to thank Ab Ream, FEMP O&M Program Manager, for his leadership and support of this program.

The authors would like to thank the energy and facility staff members of the federal agencies who have over the years provided us with their ideas and efforts regarding metering needs and practices – all of which have been very helpful in compiling this guide. In particular, we acknowledge the following individuals who supported the development of the case studies: Ed Phillips and Mark Toscano of the Brookhaven National Laboratory, Rich Oswald and Bill Quick at the General Services Administration's Kastenmeier Federal Courthouse, Karen Curran of the General Services Administration Energy Center of Expertise, and Greg Leifer of the National Institutes of Health. In addition, we would like to thank Bill Koran of Portland Energy Conservation, Incorporated (PECI) for his insights on the uses of metered data and Jim Heller of the Naval Facilities Engineering Services Center for his perspectives and experience with metering systems.

The authors would also like to thank Bill Chvala and Bill Sandusky, both of Pacific Northwest National Laboratory (PNNL), for their review and suggestions in the development and production of this guide.

Finally, the authors would like to extend their appreciation to PNNL's document production team – Dave Payson, Kathy Neiderhiser, and Elaine Schneider – for the conscientious, team-oriented, and high-quality assistance they brought to this project.

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Acronyms

AEC	Architectural Energy Corporation
AMR	automated meter reading
API	Application Program Interface
BAS	building automation system
BNL	Brookhaven National Laboratory
CBECS	Commercial Buildings Energy Consumption Survey
CDD	cooling degree days
cfm	cubic feet per minute
CT	current transformer
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
ECM	energy conservation measure
EIS	Energy Information System
EPAct	Energy Policy Act
ESPC	energy savings performance contract
EUI	Energy-Use Intensity
FEDS	Facility Energy Decision System
FEMP	Federal Energy Management Program
GAO	Government Accounting Office
GSA	General Services Administration
HDD	heating degree days
HSPD	Homeland Security Presidential Directive
HVAC	heating, ventilation, and air conditioning
IT	information technology
LAN	local area network
LEED-EB	Leadership in Energy and Environmental Design – Existing Buildings
LEED-NC	Leadership in Energy and Environmental Design – New Construction
LIPA	Long Island Power Authority
M&V	measurement and verification
MCC	motor control center
NFPA	National Fire Protection Association
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NYPA	New York Power Authority
O&M	operations and maintenance
ODBC	Open Database

PNNL	Pacific Northwest National Laboratory
RF	radio frequency
SCADA	supervisory control and data acquisition
scfm	standard cubic feet per minute
SQL	structured query language
TCP/IP	Transmission Control Protocol/Internet Protocol
THD	total harmonic distortion
TOU	time-of-use (pricing)
VAR	Volt-amps reactive
WAN	wide-area network
WBE	Whole Building Energy
XML	extensible markup language

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Chapter 1 Introduction and Overview

The purpose of this guide is to provide you, the Facility/Energy manager and practitioner, with useful information about energy and resource metering, the relevant metering technologies, communications, applications for data, and ideas for energy and cost savings. In addition, this guide assists in the implementation of metering requirements in accordance with the *Energy Policy Act of 2005* (EPAct 2005). To make this guide useful and to reflect your needs and concerns, the authors met with Facility and Energy managers via Federal Energy Management Program (FEMP) workshops and annual conferences. In addition, the authors conducted literature searches and contacted numerous vendors and industry experts. The information and case studies that appear in this guide resulted from these activities.

It needs to be stated at the outset that this guide is designed to provide information on effective metering strategies as they apply to systems and equipment typically found at federal facilities. This guide is not designed to provide the reader with step-by-step procedures for installing or connecting metering equipment. Rather, this guide first directs the user to qualified installation entities and the manufacturer's specifications and recommendations. In no way should the recommendations in this guide be used in place of manufacturer's recommendations. The recommendations in this guide are designed to supplement those of the manufacturer – or, as is all too often the case, provide guidance for systems and equipment for which all documentation has been lost.

As a rule, this guide will first defer to the manufacturer's recommendations on equipment metering installation and operation.

STOP **Actions and activities recommended in this guide should only be attempted by trained and certified personnel. If such personnel are not available, the actions recommended here should not be initiated.** STOP

1.1 About This Guide

This guide is designed to serve as a resource for facility and energy management and technical staff. It does not try to represent the universe of metering-related material. Rather, it attempts to:

- Provide needed background information on why metering is important and the potential for savings from properly executed metering programs.

- Define the major approaches to metering and provide guidance on the structure of an effective metering program.

This guide is designed to serve as a resource for facility and energy management and technical staff.

A competent metering program requires the participation of staff from five well-defined areas within the overall facilities organization – these are Operations, Maintenance, Engineering, Training, and Administration.

- Provide information on state-of-the-art metering and communications technologies.
- Highlight the more common and applicable uses for metered data as they apply to the federal sector.
- And finally, identify information sources and contacts to assist you in getting your job done.

1.2 Target Audience

Facility and energy managers, practitioners, and technical staff represent the prime focus of this document. However, a competent metering program requires the participation of staff from five well-defined areas within the overall facilities organization – these are Operations, Maintenance, Engineering, Training, and Administration. While a given site may not have all five of these areas as separate entities, these functions are provided for within the organization. It is these staff that are targeted.

A successful metering program requires cooperation, dedication, and participation at all levels and cannot succeed without everyone involved understanding the basic principles and supporting the cause.

1.3 Organization and Maintenance of the Document

It is the intention of the authors to update this guide periodically as new metering technologies and procedures are developed and employed.

The guide consists of nine chapters. The first chapter is an introduction and an overview. Chapter 2 provides the rationale for "Why Metering?" Chapter 3 discusses metering planning, providing key issues and highlighting their importance. Chapter 4 examines metering approaches and their role in an overall metering program. Chapter 5 looks at the different metering technologies by major utility type; electricity, natural gas, steam, high temperature/chilled water, and potable water. Chapter 6 focuses on metering communications and data storage. Chapter 7 describes the various uses for metered data and options on data analysis via energy information systems. Chapter 8 covers the topic of metering economics and the different options for the federal sector for metering financing. Chapter 9 finishes the guide with federal-sector case studies and success stories.

The metering facility management environment is in a constant state of evolution and the technologies and vocabularies are ever expanding. Therefore, a glossary of terms is presented in Appendix A. Appendix B provides a copy of Section 103 of the *Energy Policy Act of 2005*. Appendix C includes applicable codes and standards as related to metering equipment and installations. And finally, Appendix D is a form that can be used to submit suggestions or revisions to this guide.

Again, we designed this to be a useful document, and we welcome your input to help us keep it current. Please feel comfortable to make suggestions for changes, additions, or deletions using the form found in Appendix D.

1.4 References

Energy Policy Act of 2005 (EPAct). 2005. Public Law 109-58, as amended, Section 103, Energy Use Measurement and Accountability, Section 543 (42 USC 8253), (e) Metering of Energy Use.

It is the intention of the authors to update this guide periodically as new metering technologies and procedures are developed and employed.

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Chapter 2 Why Metering?

2.1 Introduction

Energy managers have long known the value of energy use data. And with recent advances in energy-use metering – increased functionality at lower costs – obtaining these data in a cost-effective manner is now becoming a standard practice. Whether energy managers are trying to comply with legislated and mandated metering requirements, or looking to apply accepted building management best practices such as utility bill verification or benchmarking, today's metering technologies can provide the information needed to meet energy goals, save money, and improve their building operations.

Today's metering technologies can provide the information needed to meet energy goals, save money, and improve building operations.

2.2 Definitions (DOE 2006)

Advanced meters. Advanced meters are those that have the capability to measure and record interval data (at least hourly for electricity), and communicate the data to a remote location in a format that can be easily integrated into an advanced metering system. EPAct Section 103 requires at least daily data-collection capability.

Advanced metering system. A system that collects time-differentiated energy usage data from advanced meters via a network system on either an on-request or defined schedule basis. The system is capable of providing usage information on at least a daily basis and can support desired features and functionality related to energy-use management, procurement, and operations.

Standard meters. Electromechanical or solid state meters that cumulatively measure, record, and store aggregated usage data that are periodically retrieved for use in customer billing or energy management. Meters that are not advanced meters are standard meters.

The importance of metering can be summed up in the Energy Manager's maxim:

If you don't collect it – you can't measure it.
If you don't measure it – you can't manage it.

See Appendix A, Glossary of Common Terms, for additional advanced metering terms and definitions.

2.3 Motivation

The *Energy Policy Act of 2005* (EPAct 2005) requires federal sites to consider the application of meters for their buildings. This EPAct requirement was based on the idea that the data provided by the meters (and its subsequent analysis and actions) will greatly help sites reduce their energy use and costs in a cost-effective manner. Beyond EPAct, motivation to consider the application of meters is also provided in agency policy for energy efficiency and/or sustainable operations, as well as through the efforts of the local utility companies looking to better manage or reduce their customer loads on an increasingly constrained electric grid. Finally, while the application of meters will not be cost-effective for all utilities in all locations, its consideration for all applications is necessary for sites looking to improve their operations.

2.3.1 Legislated Metering Requirements (EPAct 2005)

Section 103 of the EPAct 2005 (Public Law 109-58) requires that "all Federal buildings shall, for the purposes of efficient use of energy and reduction in the cost of electricity used in such buildings, be metered … to the maximum extent practicable." This requirement of law is the driving force behind the ongoing efforts of federal agencies to meter their electric use. The primary metering requirements established in Section 103 of EPAct, Energy Use Management and Accountability,[1] are summarized by these key points:

- By October 1, 2012, all federal buildings will be metered subject to determination of practicability.
- Installed meters will support the efficient use of energy and reduction in cost of electricity used.
- Advanced metering devices that provide interval data on at least a daily basis will be used subject to practicability.
- Metered data will be used made available to federal facility managers.

Metering Beyond the EPAct Requirements

As federal sites move forward in developing their metering programs, they are encouraged to consider meter applications above the EPAct requirements. In addition to metering building electricity use, also consider metering (where cost-effective) water, natural gas, steam, chilled water, and compressed air. Also consider metering beyond the building level and instead look at sub-metering consumption by tenants within buildings and/or at the equipment level to support optimization activities.

The complete text of EPAct Section 103 can be found in Appendix B, Energy Policy Act Requirements.

2.3.2 Department of Defense Metering Requirements (DoD 2005a)

The facilities owned and operated by the U.S. Department of Defense (DoD) account for approximately two-thirds of the total facility energy used by federal buildings in 2005. In an effort to better manage their energy use and costs, DoD Instruction 4170.11, Installation Energy Management (November 22, 2005), was issued. Paragraph 5.2.4.2, Metering, establishes the expanded metering requirements for DoD buildings to include metering of electricity, natural gas, and water on appropriate facilities (those where "metering would be cost-effective and practical as a management enhancement tool"), and the metering of steam at steam plants. DoD also requires that meters be installed on all new construction and utilities systems renovation projects exceeding $200,000. Chapter 10 of the

[1] The metering requirements of EPAct amended Section 543 of the National Energy Conservation Policy Act (42 U.S.C. 8253).

Department of Defense Energy Manager's Handbook (DoD 2005b) provides additional clarification for sites on meeting the requirements of the Instruction.

Table 2.1 presents a summary of the recent legislative and metering requirements by establishing authority.

Table 2.1. Federal Metering Requirements Summary

	Establishing Authority		
	Energy Policy Act of 2005	DoD Instruction 4170.11	Executive Order 13423
Metering Requirements Section	Section 103: Energy Use Management and Accountability	Paragraph 5.2.4.2: Metering	Not required in Executive Order.
Applicability	All agencies	DoD facilities	All agencies
Key Requirements	- All buildings - Where practicable - By October 1, 2012 - Meter electricity - Hourly interval data (minimum) collected at least daily	- Meter electricity, natural gas, and water in "appropriate facilities" by 2012. - Electricity, natural gas, and water meters with interval and remote reading capabilities on all new construction and renovation projects exceeding $200,000. - Steam will be metered at plants	The Instructions for Implementation encourage that meters be applied to "measure consumption of potable water, electricity, and thermal energy in Federal buildings and other facilities and grounds." The Instructions also recommend considering the inclusion of meters in alternatively financed projects.
Supporting Documents	Guidance for Electric Metering in Federal Buildings (DOE/EE-0312)	Department of Defense Energy Managers Handbook, Chapter 10	Implementing Executive Order 13423, paragraph VI.A. (3) Metering.

By October 1, 2012, all federal buildings will be metered subject to determination of practicability.

2.3.3 Other Metering Drivers

Increasing meter functionality, declining costs of meters, and a growing recognition of the value of metered data also contribute to the expanded use of energy/utility metering. Examples include

- EPAct Section 1252, Smart Meters, requires states to investigate requiring the utilities to offer time-based rates to their customers. Electric utilities directed to offer time-based rates will be required to provide the customers on the time-based rate with an advanced meter. (See Chapter 8 for more details.)
- The Leadership in Energy and Environmental Design certification for exiting buildings, LEED-EB, allows for up to three energy credits for the application of continuous metering on energy-using systems. LEED-EB also requires metering energy output from onsite renewable energy systems.

Regarding the LEED certification for new construction, LEED-NC, metering may be used in support of the energy credit for measurement and verification.

2.3.4 Business Case for Metering

Outside of single-building sites, there is limited building or equipment sub-metering within the federal sector. Single building sites are metered for total use by their servicing utility providers, while multi-building sites usually rely on a master meter provided by the utilities at the utilities' points of entry to the site. Sites are billed by their utility providers based on the cumulative usage readings obtained from these utility, or revenue, meters over the billing period, usually about one month. But now consider the application of meters to individual buildings and even energy-intensive equipment that provides facility managers and operators real-time information on how much energy has been or is being used. This type of information can be used to assist in optimizing building and equipment operations, in utility procurements, in building energy budget planning and tracking, and so on.

It is important to keep in mind that meters are not an energy efficiency/energy conservation technology per se; instead, meters and their supporting systems are devices that provide building owners and operators data that can be used to:

How the metered data are used is critical to a successful metering program.

- Reduce energy/utility use
- Reduce energy/utility costs
- Improve overall building operations
- Improve equipment operations.

How the metered data are used is critical to a successful metering program. Depending on the type of data collected, it can enable the following practices and functions:

- Verification of utility bills
- Comparison of utility rates
- Proper allocation of costs or billing of reimbursable tenants
- Demand response or load shedding when purchasing electricity under time-based rates
- Measurement and verification of energy project performance
- Benchmarking building energy use
- Identifying operational efficiency improvement opportunities and retrofit project opportunities

- Usage reporting and tracking in support of establishing and monitoring utility budgets and costs, and in developing annual agency energy reports.

Ultimately, the business case for metering energy/utility use is based on the anticipated benefits to the site. Most of the metered data uses listed above will result in energy cost savings that can be used to justify the cost to purchase, install, and operate the metering system. The degree of cost savings realized depends on the unit cost of the energy/utility being saved and on the effectiveness with which the site analyzes the data and acts upon its findings/recommendations. But other potential benefits should also be considered as part of the metering business case. Examples can include

- Supporting efforts to attain Energy Star and/or LEED-EB certifications
- Promoting tenant satisfaction by providing information that tenants find useful in managing their operations
- Prolonging equipment life (and reducing capital investment requirements) and improving its reliability by verifying the efficient operation of equipment
- Assessing the impact of price utility price fluctuations prior to or as they happen, allowing sites/agencies to address budget shortfalls on a proactive basis.

Ultimately, the business case for metering energy/utility use is based on the anticipated benefits to the site.

2.4 References

DoD. 2005a. Department of Defense Instruction 4170.11, *Installation Energy Management*. Available at: http://www.dtic.mil/whs/directives/corres/pdf/417011p.pdf

DoD. 2005b. *Department of Defense Energy Manager's Handbook.* Available at: http://www.acq.osd.mil/ie/irm/irm_library/DoD%20Energy%20Manager%20Handbook%20Aug%202005.doc

DOE. 2006. *Guidance for Electric Metering in Federal Buildings*. DOE/EE-312. Available at: http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf

Energy Policy Act of 2005 (EPAct). 2005. Public Law 109-58, as amended, Section 103, Energy Use Measurement and Accountability, Section 543 (42 USC 8253), (e) Metering of Energy Use.

U.S. Green Building Council website for LEED for Existing Buildings. Available at: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=221

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Chapter 3 Metering Planning

3.1 Introduction

EPAct requires that all federal buildings be metered for electricity, where practicable, by October 1, 2012. This allows agencies several years to design and install their metering systems, and rightfully so since implementing a metering program requires thorough planning. In this case, planning refers to a deliberative process that, at a minimum, identifies key actions, milestones, and responsible individuals that will result in a successfully installed and operating metering system and program. In the end, a successful metering system and/or program will satisfy each of these objectives:

- Provide appropriate and accurate data in a timely manner
- Complete the analysis of data in a timely manner
- Provide data and analysis results to users in a format that leads to actions
- Operate continually and effectively on a daily and annual basis.

3.2 The Need for a Metering Plan

Developing a metering plan should be the first step at any site that is initiating a metering program. A site metering program can take several years to fully implement, especially at sites that have many buildings and/or sites that will meter multiple utilities. Over this implementation period, a number of significant and potentially complex questions will need to be addressed, and sometimes difficult decisions made. Effectively addressing these questions and issues will be greatly assisted by having a metering plan in place that:

- Establishes metering program objectives
- Identifies current and future metering needs
- Offers the opportunity to obtain and maintain management and stakeholder support
- Ensures consistency in decision making as the program development process moves forward
- Identifies key program milestones and assign individuals with lead responsibilities
- Provides for ongoing metering program monitoring and, where appropriate, adaptation.

Developing a metering plan should be the first step at any site that is initiating a metering program.

3.3 Steps to Consider in Your Metering Plan

There are many approaches a site can use to develop a metering plan. The approaches used at a given site will vary based on factors such as site mission, building construction, geography, utility expenses, and agency policy. This means a one-size-fits-all approach ***should not*** be applied to the development of a site metering plan.

Whichever approach a site uses in its planning effort, there are key elements that should be addressed for all utility metering programs (FEMP 2007):

- Establish program goals and objectives
- Identify needs to support selected analysis approaches
- Develop and apply evaluation criteria
- Implementation, design, and installation
- Performance validation and persistence.

Figure 3.1 provides a flow chart of the key steps in the metering planning process.

3.3.1 Establish Program Goals and Objectives

The critical first step for all metering programs is to establish the site's overall metering objective. While the ultimate goal of the metering program is to reduce utility use and/or costs, how this is done will depend on how the metered data are used. Some of the more typical uses include cost allocation among tenants, bill verification, demand management, and energy use diagnostics. (A complete list of metered data uses is presented in Chapter 7.) Examples of possible objectives might be:

- To fully enable energy bill allocation throughout an entire facility.

- To effectively manage electric loads to minimize costs under a time-based rate schedule.

- To identify system-specific operational efficiency opportunities.

- To formalize the outcomes of each objective. For example, if the objective is to enable full bill allocation, an outcome might be to reduce energy costs by 10 percent. If the objective is to minimize costs under a time-based rate schedule, an outcome might be to reduce electric demand charges by 20 percent.

Some Questions to Consider in Developing Your Objectives

- What are the annual utility costs for your facility?
- Who are the primary energy users and why?
- What operations actions can help reduce utility costs?
- Where is the poorly designed or operating equipment?
- What equipment should be replaced and when?
- Do like buildings use similar amounts of energy?
- Do buildings have similar operating schedules?
- Do buildings have unique operating requirements?
- By building, how much energy do you use daily? Weekly? Monthly?
- Are your energy savings strategies/projects producing results?
- What utility rate opportunities can you take advantages of?
- Are there regional or national/agency initiatives to address specific utility usage issues (e.g., water management)
- Has utility price volatility been, or could it be, an issue at your site?

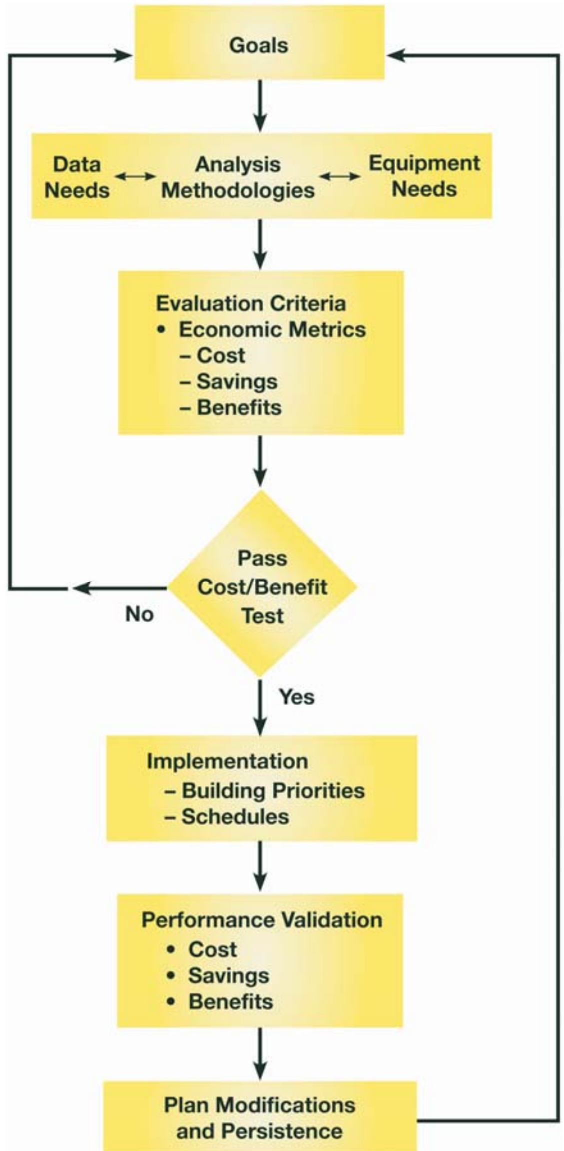

Figure 3.1. Metering Planning Process

3.3.2 Identify Needs to Support Selected Analysis Approaches

The information obtained in this step is used to ensure that the necessary data are obtained and its analysis is supported. Inclusive is the survey of any existing metering components that are operational and in use as they may support the new program's goals and objectives.

- Data needs serves as the starting point for this portion of the plan's development. What

Management and Stakeholder Support
Obtaining the short- and long-term support necessary for a successful metering program begins with having the buy-in of the building owner/manager and its stakeholders – occupants or programs that are affected by the availability and cost of the utility services, and the IT staff. Enlisting these parties in the development of your goals and objectives provides an opportunity to educate them on the potential benefits of metering to them, hear their concerns, incorporate their operational requirements into the overall plan, and prepare them to be users of the system when installed

specific types of data are needed to support the program's goals and objectives. For example, allocation electricity costs based on actual use will require (at a minimum) kWh and kW data at the building level or for portions of the buildings occupied by different tenants. In addition, the metering system will need to have the ability to identify and notify each organizational unit of its consumption and demand on a periodic basis. Table 3.1 presents the types of data required to support various building electricity metering approaches.

An important question to ask is what specific types of data are needed to support the program's goals and objectives.

Table 3.1. Example Electric Data Requirements (AEC 2003)

Goal	Metering Points	Data Interval	Minimum Update Rate
Cost Allocation	Demand and energy for each tenant or agency to be billed	As frequent as required to support utility rate	Monthly
Load Aggregation	Demand and energy for each facility to be included in the aggregation	As frequent as required to support utility rate	Monthly
Utility Rate Analysis	Demand and energy	As frequent as required to support utility rate	Monthly, or as required to support analysis
Power Quality	Suggested: Amps, volts, VAR, harmonic data	As frequent as required for waveform capture	Daily
Energy System Diagnostics	Depends on types of diagnostics, use demand and energy for consumption-related diagnostics	Suggestions: • 15 minutes • Shorter intervals for end use diagnostics involving cycling analysis	Daily More frequently for real-time analysis and reporting
ESPC Monitoring and Verification	Demand and energy	As frequent as required to support M&V requirements; hourly may be sufficient	Monthly
Design Information	Demand and energy	Hourly or daily	As required for design projects
Management Reporting Requirements	Depends on reporting requirements; demand and energy for consumption-related reporting	Depends on reporting requirements	As required for reporting frequency

- Analysis methodologies are a critical component of a site's metering program. Data by itself is not of much use without some analysis to determine what it means. There are many tried and true methods of trend analysis, for example, and many commercially available software tools and service providers that can help make sense out of the enormous amounts of data.

- Equipment needs are based on the data requirements and the analysis methodologies identified, and should identify what types of metering/ monitoring equipment and hardware/software tools would be most appropriate to provide that data and its communication and storage.

- Survey existing metering systems. Many multiple building sites have some level of building metering or sub-metering in place. When this is the case, a survey of this existing metering equipment that identifies the type of meter, its location, operating status, capabilities, and actual data collection/ communications and applications needs to be completed. Can the existing metering system support the new program's goals and objectives? Can the existing equipment be put to better use?

- Staffing resources needed to operate the metering system when in place are also critical to a successful metering program. This includes the staff necessary to start up the metering system as well as the staff/contracted support that will provide the ongoing operations and maintenance of the installed metering system.

- Security requirements vary widely across the federal sector. In general, information technology (IT) staff should be asked to participate in the development of the metering program planning efforts at the very beginning of the process.

3.3.3 Develop and Apply Evaluation Criteria

Meters should be applied where they will lead to a cost-effective reduction in utility use and/or costs. Determining which buildings can be metered cost-effectively requires that criteria be established and applied that take into account the life-cycle costs to meter and the benefits to be realized. For example, sites may decide to install meters on all utilities at the building level when the estimated simple payback period is 10 years or less. In some cases, the criteria are stipulated (see DoD Instruction 4170.11), but in the remaining cases, a determination of cost-effectiveness will need to be made.

The primary variables that impact the cost-effectiveness of meters are (see Chapter 8 for detailed discussion):

- The annual utility cost of the building being metered

- The cost to purchase and install the meter and associated hardware

Meters should be applied where they will lead to a cost-effective reduction in utility use and/or costs.

- Expected savings resulting from the productive use of data, typically in the range of 2 percent to 10 percent, but sometimes higher depending on how the metered data are used

- Site economic criteria – usually payback period.

In cases where a particular application does not pass the evaluation criteria, the input variables – and possibly the evaluation criteria – should be reviewed and, when appropriate, adjusted to allow for re-evaluation. For example:

- Review estimated building utility consumption estimates. Does the estimated consumption account for energy intensive operations or building operations during nights or on weekends?

- Does the cost of the meter used in the estimate include functionality that exceeds the stated goals?

- Can the estimated savings be revised? Are there additional uses for data that will result in increased energy and/or cost savings?

- Should the payback period be lengthened?

There may be a need or a greater benefit to metering some buildings and/or some utilities before others.

Cases where applications do not pass the site-developed criteria should be documented. This will allow the potential application to be reconsidered once the program is up and running and as economic (utility rate increases) and policy directions (laws, executive orders, regional initiatives) dictate.

3.3.4 Implementation, Design, and Installation

The planning process up to this point has been largely analytical. Based on the goals, objectives, analysis needs, and application of evaluation criteria, there is now enough information to design the actual metering system. Elements of the implementation, design, and installation steps include the following sub-elements discussed below:

- System financing, or how much funds are available and how will these funds be obtained, needs to be addressed early in the design process and revisited once cost estimates based on actual designs are completed. Chapter 8 provides a summary of the many financing considerations for federal sites in terms of how a project may be funded and which funding option is best for them.

- Prioritization of buildings and/or utilities to be metered. There may be a need or a greater benefit to metering some buildings and/or some utilities before others. For example, funding will be made available incrementally over several years, while initial applications may be based on total electricity use or geography (buildings in close proximity to each other).

- The design of the metering system hardware application needs to
  - Satisfy functional requirements
  - Define a system architecture
  - Develop equipment specifications
  - Review and refine the cost estimate to purchase and install the metering system.

- An installation plan that addresses the following:
  - A timeline for the installation of equipment at buildings and on sub-systems. Installation plans at federal sites should ensure that the EPAct deadline of October 1, 2012, for metering electricity in buildings is met.
  - The order of equipment installed when installation is phased
  - Commissioning the system components to ensure that they are operating as intended before accepting the installation as completed.
  - Training of site staff responsible for the maintenance of the system components and the ongoing operations activities.

3.3.5 Performance Validation and Persistence

Once the metering system is up and running, the overall program focus shifts to making sure:

- Accurate data are obtained and put to timely productive use, and
- The metering system continues to operate effectively and reliably.

The application of the data, or, more correctly, the effective analysis of data and the subsequent actions that follow, will lead to utility use and/or cost savings. These are the very savings that were used to justify the installation of the metering system. But of equal importance is the continued effective operation of the metering system and program. The following activities should be addressed in the metering plan to ensure the sustained operation of the metering system and program.

The effective analysis of data from a metering program and the subsequent actions that follow, will lead to utility use and/or cost savings.

- Identify the funding resource requirements necessary to maintain the metering system equipment and staff (inclusive of outsourcing), data collection, analysis, and reporting (to system users) activities. Funding will need to be provided on an annual basis as part of the facility's operating budget. Consider including annual training for system operators.

- Review on a regular basis the effectiveness of the metering program. Are the program's goals being met? If not, what measures should be taken to improve results?

- Assess new opportunities or needs. Re-evaluate potential applications that did not pass the evaluation criteria, especially when utility rates increase or if metering prices decline. Also consider additional applications such as utilities that were not included in the initial plan for energy-intensive equipment.

3.4 References

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Chapter 4 Metering Approaches

4.1 Introduction

Metering provides the information that ***when analyzed*** allows the building operations staff to make informed decisions on how to best operate mechanical/ electrical systems and equipment. These decisions will ultimately affect energy costs, equipment costs, and overall building performance. Metering can take place at a variety of points within an electrical or mechanical system and can encompass the collection of electricity, natural gas, water, steam or other fluid data. The decision of where and what to meter is determined by your metering objectives and should be a focus of your metering plan. While metering at the end-use or circuit level has application and will be described, our focus will center on higher-level whole-building utility metering.

At the outset, it should be noted that metering in and of itself saves no energy or dollars. In fact, it cost money to meter; the purchase and installation of the metering, the communications or meter-reading expense, and the time necessary to process and interpret data. A metering program can be a costly and time-consuming endeavor. The key to a successful metering program lies in the ability to make use of the output of a meter. Metered data need to be converted to information from where actions and projects are developed and implemented.

The decision of where and what to meter is determined by your metering objectives and should be a focus of your metering plan.

4.2 Generic Approaches

The four predominant levels of resource metering (EPRI 1996) are:

- One-time/spot measurement (system/sub-system)
- Run-time measurement (system/sub-system)
- Short-term monitoring (system/sub-system/whole building)
- Long-term monitoring (system/whole building)

Each level has its own unique characteristics – no one monitoring approach is appropriate for all metering activities. A short description of each monitoring level is provided below. It should be noted that while the four levels of resource metering presented can be applicable to measurement and verification (M&V) of energy projects, the authors of this guide recommend the International Performance Measurement and Verification Protocol (IPMVP 2002) as a particularly good reference for M&V protocols.

4.2.1 One-Time/Spot Measurements

One-time measurements are useful in many "baseline" activities to understand instantaneous energy use, equipment performance, or loading. These measurements become particularly useful in trending equipment performance over time.

> **One-Time/Spot Measurement Advantages**
> - Lowest cost
> - Ease of use
> - Non-intrusive
> - Fast results
>
> **One-Time/Spot Measurement Challenges**
> - Low accuracy
> - Limited application
> - Measures single operating parameter

For example, a spot measurement of a boiler-stack exhaust temperature, taken periodically (e.g., monthly) and trended over time, can be very diagnostic of boiler efficiency.

Related to energy performance, one-time measurements are useful when an energy-efficiency project has resulted in a finite change in system performance. The amperage of an electric motor or lighting system taken before and after a retrofit can be useful to quantify system savings – assuming similar usage (hours of operation and load profile) before and after.

Equipment useful in making one-time/spot measurements include clamp-on amp probes, contact and non-contact temperature devices, non-intrusive flow measurement devices, and a variety of combustion-efficiency devices. Most of these measurements are obtained and recorded in the field by the analyst.

4.2.2 Run-Time Measurements

Run-time measurements are made in situations where hours-of-operation are the critical variable. These measurements are prevalent where an energy efficiency project has impacted the use (i.e., hours of operation) of a device. Appropriate applications for run-time measurements include the run times of fans and pumps, or the operational characteristics of heating, cooling, or lighting systems.

> **Run-Time Measurement Advantages**
> - Low cost
> - Relatively easy of use
> - Non-intrusive
> - Useful for constant-load devices
>
> **Run-Time Measurement Challenges**
> - Limited application
> - Measures single operating parameter
> - Requires additional calculations/assumptions

Because run-time measurements do not capture the energy-use component of the system, these measurements are typically used in conjunction with one-time/spot measurements. Equipment useful in making run-time measurements include a variety of stand-alone (battery-operated) data loggers providing a time-series record of run-time. Most of these devices are non-intrusive (i.e., the process or system is not impacted by their use or set-up) and are either optically triggered or take advantage of the electromagnetic characteristics of electrical devices. Run-time measurements are usually obtained in the field by the device, recorded to memory, and then downloaded by the analyst at a later date.

4.2.3 Short-Term Measurements/Monitoring

Short-term monitoring combines both elements of the previous two levels into a time-series record of energy or resource use: magnitude and duration. Typically, short-term monitoring is used to verify performance, initiate trending, or validate energy efficiency improvement. In this level, the term of the monitoring is usually less than one year, and in most cases on the order of weeks to months. In the case of energy efficiency improvement validation, also known as measurement and verification, these measurements may be made for two-weeks prior and post installation of an efficiency improvement project. These data are then, using appropriate engineering and statistical methods, extrapolated over the year to report the annual impact.

Short-Term Measurement Advantages

- Mid-level cost
- Can quantify magnitude and duration
- Relatively fast results

Short-Term Measurement Challenges

- Mid-level accuracy
- Limited application
- Seasonal or occupancy variance deficient
- More difficult to install/monitor

Equipment useful in short-term monitoring includes a host of portable, stand-alone data loggers capable of multivariate time-series data collection and storage. Most of these data loggers accept a host of sensors including temperature, pressure, voltage, current, etc., and have standardized on input communications (e.g., 4 to 20 milliamps or 0 to 5 volts). These loggers are capable of recording at user-selected intervals from fractions of a second, to hourly, to daily recordings. These systems usually rely on in-field manual downloading or, if available, modem and/or network connections.

4.2.4 Long-Term Measurements/Monitoring

Long-term monitoring also makes use of time-series recording of energy or resource use, but over a longer duration. Different from short-term use, this level focuses on measurements used in long-term trending or performance verification. The term is typically more than a year and quite often the installation is permanent. Metering at the whole-building level is typically a long-term, permanent installation metering. This level of metering is the target of the Energy Use Measurement and Accountability portion of the *Energy Policy Act of 2005* (EPAct 2005).

Long-Term Measurement Advantages

- Highest accuracy
- Can quantify magnitude and duration
- Captures most variance

Long-Term Measurement Challenges

- High cost
- Most difficult to install/monitor
- Time duration for result availability

Useful applications for this level of monitoring include situations where system use is influenced by variances in weather, occupant behavior, or other operating conditions. Other applications include reimbursable resource allocation, tenant billing activities, or in cases where the persistence of energy or resource savings over time is at issue.

Equipment useful in long-term monitoring included a variety of data loggers, utility-grade meters, or fixed data acquisition systems. In most cases these systems communicate via a network connection or a phone modem to a host computer and/or over the internet.

4.3 The Metering Hierarchy

Given the above described metering approaches, there is a logical order, or hierarchy, to consider as you look to maximize your metering value while

In many cases, the objective of end-use monitoring is equipment performance, whether to identify inefficiency or validate savings estimates.

minimizing your metering cost. Figure 4.1 presents this concept as a function of level of effort and diagnostic capability. This proposed hierarchy starts at the most aggregate level of data collection and processing – the *whole-building* meter. Assuming access to interval electric data, this meter and resulting data can be diagnostic in identifying trends and variance in whole-building performance. In addition, these data can useful in understanding the operation and efficiency of major building systems (e.g., chillers, boilers, air handlers). While the resolution of whole-building data may not be fine enough to identify specific operational or efficiency issues, it can often be used to "frame the question" of what equipment/system is performing inconsistently and in need of further exploration.

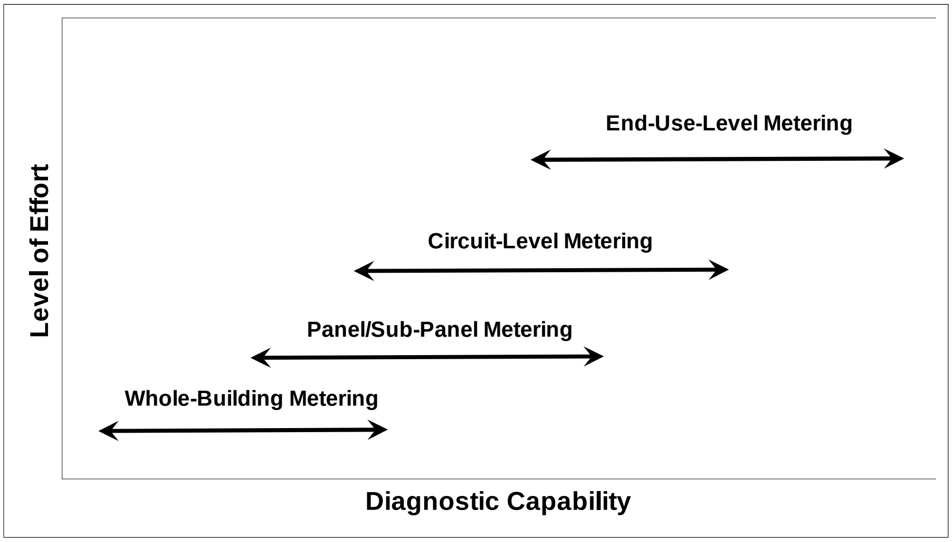

Figure 4.1. Metering Hierarchy

If the whole-building meter represents the most aggregate level, the next finer level is at the *electrical panel/sub-panel*. This second tier in the metering hierarchy focuses on loads connected at a panel (or sub-panel) level as aggregations of specific loads. Examples of panel-level monitoring include lighting panels or motor panels (i.e., motor control centers – MCCs) where hours of operation or efficiency project validation are of interest. Metering at this level incorporates a variety of dedicated or portable metering equipment or data loggers. The report titled *Portable Data Loggers Diagnostic Tools for Energy-Efficient Building Operations* (PECI 1999), does a particularly good job of describing some of the equipment useful for metering at this and the following levels.

Moving down one more level in the hierarchy, we examine *circuit-level* monitoring. The focus of metering at this level is within the panel or sub-panel and the monitoring of a specific circuit of interest. This circuit may have specific plug loads of interest such as computers or other peripherals, or may be of interest for power quality or harmonics studies.

The final level in the hierarchy, having the finest data resolution, is the end-use level. End-use monitoring serves to isolate a particular system or equipment type for detailed study. In many cases, the objective of end-use monitoring is equipment performance, whether to identify inefficiency or validate savings estimates. Chillers, boilers, cooling towers, pumps and motors are often end-use metered for performance metrics.

While the above hierarchy presents a step-wise approach to metering and efficiency diagnostics, by no means are we suggesting that all hierarchy steps need be followed sequentially when moving from whole-building to end-use metering. In fact, in some cases there should be enough information to move from the whole-building level directly to end-use level when diagnosing or trending efficiency opportunities. In cases where inefficiency by specific equipment is not so apparent, the additional steps may be beneficial to properly identify the poorly operating equipment.

Chillers, boilers, cooling towers, pumps and motors are often end-use metered for performance metrics.

4.4 References

Energy Policy Act of 2005 (EPAct). 2005. Public Law 109-58, as amended, Section 103, Energy Use Measurement and Accountability, Section 543 (42 USC 8253), (e) Metering of Energy Use.

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Chapter 5 Metering Technologies

5.1 Introduction

At the most basic level, all meters track and provide some output related to resource use – energy, water, natural gas, etc. Beyond this basic level, more sophisticated meters take advantage of additional capabilities including electrical demand tracking, power quality measurements, and multiple-meter communication for leak detection applications. For electrical systems, meters can be installed to track whole-building energy use (e.g., utility meters), sub-panel energy use (e.g., a lighting or process circuit), or a specific end use (e.g., a motor or a chiller). An increasingly useful electrical meter type is known generically as an *advanced interval meter*. These meters measure electrical demand (kW) over a pre-determined interval – commonly every 15 minutes – to match utility billing intervals. Other intervals (e.g., 1 minute, 5 minute, hourly) can be useful for examining equipment performance, trending, and start/stop characteristics.

At the most basic level, all meters track and provide some output related to resource use – energy, water, natural gas, etc.

For water, natural gas, and other flow-related applications, meters are typically in-line installations using positive displacement, insertion turbine, or pressure-related techniques. Depending on the need, any of these meters will vary in size, type, output configuration, accuracy, and price. As with electrical metering, fluid meters should have digital-output capability to take advantage of remote or automated meter reading. The interval metering concept is not exclusive to electricity metering, natural gas, water, and steam meters can also provide these often beneficial data.

Common to most meters are rated levels of performance; some of the more universal performance metrics are listed below.

Accuracy – this is usually the first metric used to determine applicability of a meter to a particular system. No meter is 100-percent accurate and most manufacturers provide a range of accuracies in their product line and corresponding prices. Accuracy could be thought of as the difference between a measured value and that of the actual value. Published accuracies often will, and should, be referenced to specific calibration procedures including equipment-traceability to National Institute of Standards and Technology (NIST 2007) equipment and procedures.

Precision/Repeatability – the precision or repeatability of a measurement entails the ability to reproduce the same value (e.g., temperature, power, flow rate) with multiple measurements of the same parameter, under the same conditions.

Turndown ratio – the turndown ratio refers to the flow rates over which a meter will maintain a certain accuracy and repeatability. For example, a steam flow meter that can measure accurately from 1,000 lbs/hr to 25,000 lbs/hr has a turndown ratio of 25:1. The larger the turndown ratio, the greater the range over which the meter can measure the parameter.

Beyond performance metrics, other criteria useful for meter selection include:

Ease of installation – regardless of technology, meters come in many different sizes, shapes, needing a variety of inputs, and offering a variety of outputs. When making specific make-and-model decisions, it is important to understand any size and weight constraints, needs for specific diameters (or lengths) of straight pipe upstream and downstream of the meter, specific electrical and communications needs, and the overall environment the meter will operate in.

Ongoing operations and maintenance – the lowest cost metering technology may not be the best choice if it has high associated maintenance costs (e.g., frequent service, recalibration, sensor replacement). As with most capital purchases, a life-cycle cost approach (including all capital and recurring costs) is recommended for decision making.

The lowest cost metering technology may not be the best choice if it has high associated maintenance costs.

Installation versus capital cost – in some situations, the cost to install a meter can be greater than the capital cost; this can be true where system shutdowns are necessary for meter installations, or where significant redesign efforts are needed to accommodate a meter's physical size, weight, or required connection. In these cases, decision makers should consider alternative technologies that may have a high first cost but a much lower installed cost. A good example of this is the use of non-intrusive metering technologies (e.g., ultrasonic flow meters) that typically have a high capital cost but often a significantly reduced installed cost.

The next several sections in this guide address metering technologies specific to electricity, natural gas, steam, potable water, and high temperature/chilled water. Each section was designed to be stand-alone, as such, some of the material may seem redundant; however, the authors felt the need for completeness for the reader who needed information on one technology at the cost of appearing redundant to multiple-technology reader.

Throughout this guide, we will first defer to the manufacturer's recommendations on equipment selection, compatibility, appropriateness for application, and all operational and maintenance activities.

STOP **Actions and activities recommended in this guide should only be attempted by trained and certified personnel. If such personnel are not available, the actions recommended here should not be initiated.** STOP

Appendix C of this guide provides a list of some of the codes and standards that are relevant to metering, metering systems and communications.

References

NIST 2007. *National Institute of Standards and Technology Policy on Traceability*. Available at: http://ts.nist.gov/Traceability/nist_traceability_policy-external.cfm

Throughout this guide, we will first defer to the manufacturer's recommendations on equipment selection, compatibility, appropriateness for application, and all operational and maintenance activities.

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5.2 Electricity Metering

5.2.1 Introduction

The measurement of electricity can be accomplished in many ways, using a variety of instrumentation, with varying degrees of accuracy and reliability. Likewise, the uses for metered electricity data are numerous – ranging from relatively simple totalized monthly kilowatt hours (kWh) to very sophisticated studies of power quality and harmonics. This section discusses the most common electrical metering parameters with the focus on those parameters offering the greatest potential for energy and operational efficiency improvements (FEMP 2007). It should also be restated that electricity metering can be a complicated and dangerous endeavor; the equipment and procedures discussed here should only be attempted by qualified staff and in compliance with the National Electric Code (NFPA.70 2007) and any local- or agency-specific codes or requirements.

The uses for metered electricity data are numerous – ranging from relatively simple totalized monthly kilowatt hours (kWh) to very sophisticated studies of power quality and harmonics.

5.2.2 Common Electrical Metering Terms

Amperes (amps): The measure of electricity flow in a conductor and usually measured with a ammeter or current transformer. The symbol for amperes is "A."

Voltage (volts): The measure of electric potential between two points in a circuit and typically measured with a voltmeter or potential transformer. The symbol for voltage is "V."

Volt-amperes (volt-amps): The measure of "apparent" rate of energy supplied to an electric load. The volt-ampere (designated VA) is defined as the voltage multiplied by the current. The volt-ampere is the metric used to rate many forms of electrical equipment.

Wattage (watts): A measure of the "real power" delivered to an electric load. Watts are defined as volt-amperes multiplied by the "power factor." As such, the real power will always be less than or equal to the apparent power.

Volt-Amps Reactive (VAR): A measure of the system's reactive power – or power stored in a system's inductive loads – and is mostly used for identifying power factor correction needs.

Power factor: The ratio of "real power" (watts) to "apparent power" (volt-amperes) and defined as the cosine of the phase angle between voltage and current. For resistive loads (in ac circuits), the voltage and current are in phase and, therefore, the cosine of the angle is unity (i.e., 1.0), resulting in a power factor of unity. For loads with reactive components (e.g., motors, electrical ballasts), the voltage and current are not in phase resulting in a power factor of less than unity. Power factors significantly less than 1.0 (e.g., 0.85) can result in surcharges from the utility due to their need to make up the balance resulting from the improper power factor. The significance of power factor is that the electric utility supplies customers with volt-amps but bills the customer for watts. A power factor below 1.0 requires the utility to generate more than the minimum volt-amps to supply the load.

Demand: A measure of the average real power over a specified time interval. Depending on the utility, the specified interval is between 5 minutes to 1 hour, with the 15-minute interval being the most common.

Peak demand: The largest value of demand occurring during the billing cycle. This value is typically used by the utility to assess peak demand billing. It is critical to understand how your utility assesses peak demand, and the associated kW charge, to be able to manage for operational and economic efficiency.

Harmonics: A measure of the electrical frequencies beyond the fundamental frequency of 60 hertz and usually labeled as the first harmonic (60 hertz), second harmonic (120 hertz), etc. Harmonics are created by non-linear loads (e.g., computer power supplies, electronic ballasts, etc.) that draw current in short pulses rather than the traditional smooth ac sine wave form. Among other problems, harmonics can cause excessive heating of metal wires and certain types of electrical interference.

Mechanical meters are the most prevalent of the three major types of electricity meters.

Total harmonic distortion (THD): THD is a measure of the content of all harmonic frequency current or voltages in relation to the fundamental current or voltage frequency. This content is usually expressed as a percentage of the fundamental frequency and is defined as the square root of the sum of the squares of the harmonics divided by the fundamental frequency.

5.2.3 Electricity Metering Technologies

There are three major types of electricity meters: (1) ***mechanical meters*** where electricity use is proportionate to movement of a mechanical dial, (2) ***electro-mechanical meters***, which are similar to the mechanical meter but with an electronic or pulse output, and (3) solid state/digital meters – also called ***advanced meters*** – these meters have no moving parts and outputs reported in a variety of digital formats. A short description of each follows (FEMP 2005):

Mechanical Meters: In terms of installed base, this meter type – due to its extensive use by utilities in the residential sector – is the most mature and has the largest fraction of the installed base. The basic function of this meter involves a metallic disk acted on by two coils; one coil generates a magnetic field proportionate to the voltage and the other a field proportionate to the current. These two fields act on the disk with the force related to the product of voltage times the current. This force causes the disk to spin at a rotational speed proportionate to the power drawn by the load(s) through the meter.

The mechanical meter is commonly found on building service entrances (usually residential and small commercial) with service voltages of 120/240 volts.

When properly installed mechanical meters have an accuracy in the range of 1 to 2 percent. Equipment costs for mechanical meters are in the range of $50 to $100. The accompanying installed cost is difficult to estimate without knowing the existing configuration, presence of a meter base, and needs for additional wiring, trenching, etc.

A significant limitation to mechanical meters is the lack of data storage and an ability to electronically communicate. Mechanical meters are in essence totalizers where data are read manually and energy use is calculated as the delta between the current and previous readings. As such, mechanical meters **do not** meet the EPAct requirements for interval data (at least hourly) nor an ability to have daily downloads.

Electro-Mechanical Meters: Similar in form and function to the mechanical meter, the electro-mechanical meter has the same basic operation with the addition of some type of optical encoder for digitizing energy use. This encoder is a device that "sees" the spinning disk and reports a signal (most commonly a pulse) at the completion of one revolution. This pulse can either be stored at the meter for future downloading or sent for collection to an ancillary data recording device. In either case, the electro-mechanical meter affords the ability to collect, record, and read the electronic representation of power use.

As with the mechanical meter, the electro-mechanical meter is usually found on building service entrances (usually residential and small commercial) with service voltages of 120/240 volts. Because these meters do not usually track demand (kW), their use is limited to smaller utility accounts.

When properly installed electro-mechanical meters have an accuracy in the range of 1 to 2 percent. Equipment costs for electro-mechanical meters are in the range of $200 to $400; retrofit costs are in the $50 to $100 range. As with all electric meters, the accompanying installed cost is difficult to estimate without knowing the existing configuration, presence of a meter base, and needs for additional wiring, trenching, etc.

Distinct from the mechanical meter, the electro-mechanical meter does allow for data storage and communication. However, most of these systems are not designed for the interval data storage and communication abilities sufficient to meet EPAct requirements. While it is possible to configure an electro-mechanical meter to meet EPAct requirements (at least hourly interval data with daily data access), the ancillary data storage and communication equipment may be cost prohibitive. If this route is being

Mechanical Meter

Advantages:
- Low cost
- Fairly accurate
- Widely used/available

Challenges:
- Manually read – most read infrequently
- No time-based recording
- Limited use for readings
- Does not meet EPAct requirements

Electro-Mechanical Meter

Advantages:
- Low/moderate cost
- Fairly accurate
- Can be automated for data recall

Challenges:
- New/retrofit solution difficult to meet EPAct
- May not have time-based recording
- Added cost

considered for EPAct compliance, consideration should be given to this ancillary equipment and configuration costs and then compared to a fully capable and integrated advanced electric meter.

Advanced Electric Meter

Advantages:

- Accurate
- Data storage and time-stamp capabilities
- Can accommodate other inputs
- Multiple output/diagnostic capabilities
- Two-way communication
- Control/alarm features
- Flexible data intervals and uses

Challenges:

- Moderate/high cost
  - More expensive as options and features increase
- More complicated/more data/staff training suggested
- Need ancillary systems for data transfer and use

Advanced (solid state/digital) Electric Meters: Different from mechanical/ electro-mechanical meters, advanced meters require no moving parts, rather they rely on sophisticated integrated circuits with current and voltage transformers, on-board memory, and communication technology.

Advanced meters are those that have the capability to measure and record interval data (at least hourly for electricity) and communicate the data to a remote location in a format that can be easily integrated into an advanced metering system. These meters measure electrical demand (kW) over a pre-determined interval—commonly every 15 minutes to match utility billing intervals. Other intervals (e.g., 1 minute, 5 minute, hourly) can be accessed and are useful for examining equipment performance, trending, and start/stop characteristics. With availability and versatility of advanced meters increasing and capital costs falling, these meters are quickly gaining market share and acceptance.

Advanced meters are usually installed on larger commercial buildings and/or facilities with large time-varying loads. In these instances, access to energy (kWh) and power (kW) data is critical to understanding energy/power uses and costs. In the federal sector, it is these meters that meet the full intent of EPAct.

Advanced meters can take a variety of shapes and sizes (also known as the meter "form factor"), from the familiar circular socket-based style to an array of rack and panel-mount configurations. Depending on the manufacturer and model, advanced meters have accuracies in the range of 0.2 to 3.0 percent, with most in the 0.2 to 0.05 percent range. Equipment costs for these meters can also vary by manufacturer and features selected; typical advanced meter cost range from $1,000 to $3,000.

Properly configured, advanced meters meet EPAct (hourly interval data with daily downloads) and most models go well beyond with advanced features. Some of the more common features of advanced meters are listed below:

- Data storage and time-stamp capabilities – meters can record and store energy, demand, and diagnostics in a time-series record with user selectable intervals.

- Accommodate other inputs – meters can receive inputs (e.g., pulses from nearby gas or water meters) and record and store these data in the same time series record.

- Diagnostic capabilities – span the electrical horizon from voltage and current diagnostics, harmonic distortion and power factor studies to voltage level and phase symmetry.
- Two-way communication – meters typically have abilities to both send and receive signals which allows remote access to change meter configurations (e.g., data intervals).
- Control/alarm features – as demand (kW) approaches target levels these meters can alarm facility staff of approaching limits and/or control equipment and systems to off-load or shut down.
- Flexible data intervals – for diagnostic purposes, these meters have flexible recording intervals, usually down to at least 1 minute. This allows facility staff to isolate suspect events in a much refined window.
- Statistics: minimum, maximum, average – meters have extensive statistical capabilities of recording, analyzing, and reporting maximum/minimum voltage and current readings, phase-to-phase relationships, harmonics, etc.
- Multiple modes of communication – most meters have capabilities from traditional phone modem to networked connections and wireless options. In addition, some meters allow for multiple communication options and include an ability to be a communications hub for other devices such as gas or water metering devices.

5.2.4 Recording Intervals

For larger commercial buildings and industrial/processing facilities, electric utilities collect, store, and determine billing amounts based on a 15-minute interval. To be able to match utility records, examine load profiles, and understand potential utility rate dollar savings opportunities – using the 15-minute recording interval is recommended.

Beyond the utility-related activities, shorter data intervals offer a host of diagnostic capabilities including identifying peak-demand contributing equipment and opportunities for targeted load shedding/shifting. As mentioned, the ability to vary the recording intervals based on diagnostic or other temporary need can be invaluable; this gives the user the power to examine refined intervals for a period and then change back to the more manageable data intervals.

5.2.5 Electric Metering Maintenance

As the world of electronics has shifted from analog to solid state, and finally to digital, maintenance of the associated electronics has been substantially reduced and reliability has increased. The electronics associated with power metering are no different than that of most other similar devices. Environmental conditions

As the world of electronics has advanced from analog to solid state, and finally to digital, maintenance of the associated electronics has been substantially reduced and reliability has increased.

play a key part in the longevity and reliability of the components. Care should be taken to minimize environmental extremes (e.g., temperature, vibration). Although the metering components can be sent to manufacturers for periodic maintenance and calibration, the functionality of the metering device can also be periodically compared to portable metering devices. Other components of the electrical metering system, for example, current and potential transformers, are generally maintenance free, provided they are originally designed for the operational and environmental conditions. The integrity of electrical connections should be checked periodically in accordance with National Fire Protection Association (NFPA) (NFPA.70 2007) and manufacturer guidance.

5.2.6 Electric Meter Data Output/Communications Considerations (FEMP 2007)

For the whole-building application of advanced electric meters, the most common data outputs are calibrated pulses (e.g., pulses/kWh). These data are usually stored at the meter in the prescribed time-series format. At periodic intervals (most often daily), the data are accessed through one of a variety of communications options – telephone modem being the most common. These data are then downloaded to a database for future processing. Chapter 6 addresses in more detail the different output and communications options.

For the whole-building application of advanced electric meters, the most common data outputs are calibrated pulses.

5.2.7 Advanced Electric Meter Specification Considerations

- Determine service voltage – Use design drawings and confirm by system walk-down. If present, understand transformer wiring and output.

- Estimate maximum amperage or power – At the main disconnect is listed the disconnect power as the maximum safe load. The real load is often less than this rating. Also need to confirm there is only one electrical feed to the building and no feeds to other buildings.

- Physical installation requirements – Where will the meter be installed, internal or external to building? Will installation use a meter base, panel, or rack-mount?

- Determine accuracy requirements – Typical accuracy of advanced electric meters is 0.2 to 0.5 percent.

- Communications requirements – How will the meter report the data: network connection, phone modem, power-line carrier, building automation system?

- Functionality requirements – At the outset, determine the required functionality first and then consider the other options and features.

- Facility staff buy-in – Make certain those staff that will be installing, maintaining, and most importantly, using the data have a voice in meter specification development.

5.2.8 Advanced Electric Meter Selection Considerations

- Don't over-buy – Good metering planning leads to judicious feature selection. Resist the temptation to capture more data than you are able to process and use.

- Consider flexibility – Balance what you need now with that you see as having future benefits. Consider separating "required" and "desired" features. Understand if features can be enabled or added later without significant retrofit expense.

- Communication interoperatability – Consider standardization on communication between meters and other data acquisition systems.

- Data processing – How will the collected data be processed? Does the metering equipment vendor offer this function/ service? Do not overlook the effort it will take to create a process to collect, store, and archive the data.

- Facility staff buy-in – Make certain those staff that will be installing, maintaining, and most importantly, using the data have a voice in meter selection.

When it comes to electric meter selection, resist the temptation to capture more data than you are able to process and use.

5.2.9 References

FEMP. 2005. *Facility Metering for Improved Operations, Maintenance, and Efficiency*. Federal Energy Management Program (FEMP), O&M Program Fact Sheet. January 2005. Available at: http://eere.energy.gov/femp/pdfs/om_metering.pdf

FEMP. 2007. *FEMP Metering Training Course Session 2: Metering Technologies, Communications, and Data Storage*. April 4, 2005. Available at: http://eere.pnl.gov/femp/metering_webcast.stm

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5.3 Fluid Metering – Natural Gas

5.3.1 Introduction

The metering of natural gas presents unique challenges when compared to other fluid (i.e., liquid) flow metering. The physical properties of natural gas, particularly its dynamic relationship between temperature and pressure, can drive metering inaccuracies unless compensated for. Accurate natural gas flow measurement usually requires the measurement of the fluid's temperature and pressure in addition to flow.

Additional constraints on natural gas metering may include the physical space available or possibly configuration and weight of the metering system. Some of the fluid metering technologies require specific lengths of pipe, both upstream and downstream of the meter for proper function. Before any technology decisions are made, discussions with equipment vendors and/or design engineers are recommended to ensure proper technology selection.

Depending on the application, flow rate, installation access, and desired accuracy, there are a number of technology options for natural gas metering. In general, measurement of natural gas volumetric flow rate is represented in standard cubic feet per minute (scfm). The actual mass of gas flowing past a point of measurement changes with its temperature and pressure. Density changes resulting from temperature and pressure differences result in differences between the energy content of like volumes of the gas. To equalize the effect of density variations when metering gas, conditions are referenced against standard temperature and pressure conditions, hence, scfm instead of cubic feet per minute (cfm). Gas meters must compensate for density differences between standard conditions and actual conditions to accurately define scfm flow rates. The most common volumetric gas metering devices fall into one of the following categories: (1) positive displacement, (2) differential pressure, and (3) velocity. In most applications, gas meters are installed downstream of pressure regulation devices and the meters are then calibrated to that pressure.

Accurate natural gas flow measurement usually requires the measurement of the fluid's temperature and pressure in addition to flow.

As is the rule for all metering, not every natural gas metering technology is recommended for every application. Careful determination of your required accuracy, access, and price point will aid in proper selection.

5.3.2 Natural Gas Metering Technologies

As mentioned, there are three primary categories of gas flow measurement relevant to federal application: positive displacement, differential pressure, and velocity (FEMP 2007). A description of each is provided below.

5.3.2.1 Positive Displacement Meters

As the name implies, a positive displacement meter functions by the fluid physically displacing the measuring mechanism and this displacement becomes the metered value. Of relevancy to natural gas measurement, the two predominant technologies are the diaphragm meter and the rotary meter. In each case, the volume of gas for measurement physically impinges on a measuring element (flexible diaphragm or rotary blower) to increment a recording dial or other output.

Figure 5.1. Typical Natural Gas Diaphragm Meter

Positive Displacement – Diaphragm Meter. By far the most common type of natural gas meter is the positive displacement "diaphragm" meter (Figure 5.1). Within this meter are usually two or more chambers separated by a moveable diaphragm. As the gas flows into the meter, it is directed by internal valves causing the chambers to alternatively fill and expel the gas. This fill/expel cycle produces near continuous flow of gas through the meter. A rotating crank mechanism converts the linear motion of the diaphragms into rotary motion which then drives an index to record the gas use. The diaphragm meter is commonly found on building service entrances with pipe connection (line) sizes of 0.75 to 2 inches. As with all natural gas metering devices, to ensure the highest accuracy, pressure and temperature compensation should be applied. When properly installed, complete with temperature and pressure compensation, diaphragm meters are accurate typically to within 1 percent. Equipment cost for diaphragm meters is in the range of $150 to $500 – depending on connection size. The related *installed cost* is difficult to estimate without knowledge of existing configuration, the need for piping, trenching/cutting of concrete, or the cost to bring the existing configuration "up to code."

Positive Displacement – Rotary Meter. The other major type of positive displacement meter for natural gas metering is the rotary flow meter. Figure 5.2 shows a typical rotary flow meter.

Rotary flow meters are highly machined-precision instruments capable of handling higher volumes and pressures than diaphragm meters. Their function relies on two figure-eight-shaped lobes that turn, in-so-doing, trapping a specific volume of fluid. As the lobes turn, the fluid is moved through the device with the fluid's flow being proportional to the rotational velocity of the rotors. Figure 5.3 highlights the function of the rotary flow meter.

The rotary flow meter is commonly found on buildings with line sizes of 1.5 to 4 inches and typically located on buildings with higher flow rates of gas.

Figure 5.2. Typical Natural Gas Rotary Flow Meter

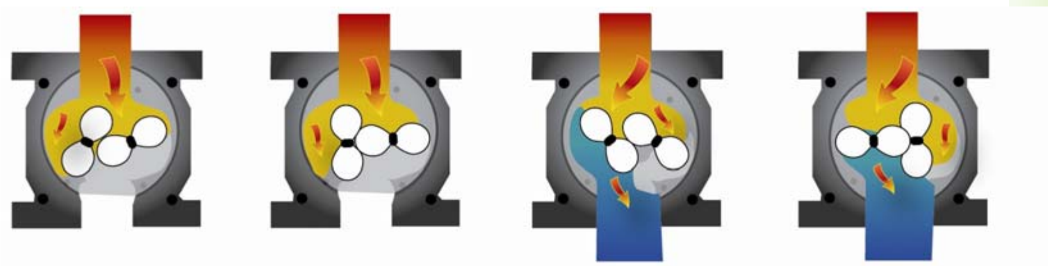

Figure 5.3. Rotary Flow Meter Function

The rotary flow meter is commonly found on buildings with line sizes of 1.5 to 4 inches and typically located on buildings with higher flow rates of gas. Rotary flow meters have accuracies in the range of 0.25 to 0.5 percent and, depending on connection size, have costs in the range of $300 to $500.

5.3.2.2 Differential Pressure Meters

All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation. Specifically, when an obstruction or orifice is placed in the path of a fluid, the fluid velocity will increase while its pressure decreases. It is this change in pressure that is measured and, via the relationship between pressure drop and the square-of-the-flow, used to calculate the fluid flow rate. There are a variety of differential pressure devices useful for gas metering, three of the more common devices are described below.

Differential Pressure – Orifice Meter. Although various-style orifices are manufactured, the basic design and operation remains the same. The orifice element is typically a thin, circular metal disk held between two flanges in the fluid stream. The center of the disk is drilled with a specific-size hole, depending on the expected fluid flow parameters (e.g., pressure and flow range). As the fluid flows through the orifice, the restriction creates a pressure differential upstream and downstream of the orifice proportional to the fluid flow rate. This differential pressure is measured and a flow rate mathematically calculated based on the differential pressure and fluid temperature. Figure 5.4 presents a diagram of a typical orifice meter.

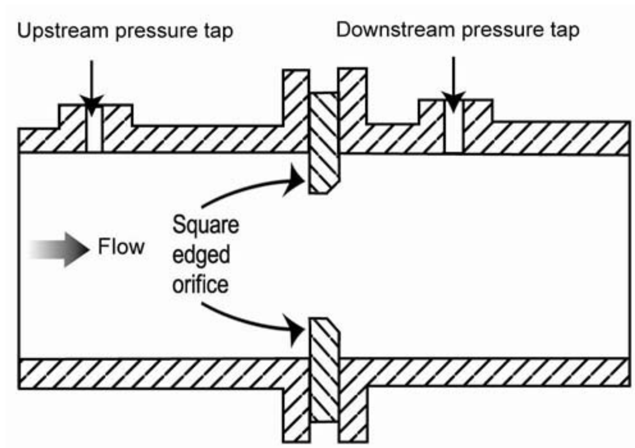

Figure 5.4. Typical Orifice Meter

The benefits of orifice meters should be traded off against the potential decrease in pressure at the end use.

Orifice meters, by design, develop significant pressure drop within the system. The benefits of this technology (i.e., its relative compactness, its accuracy, and its simple function) should be traded off against the potential decrease in pressure at the end use. For proper function, the orifice meter requires smooth flow through the orifice. For this to be assured, it requires a significant section of straight pipe both upstream and downstream of the meter. While these lengths may vary by manufacturer, typical lengths fall between 15 to 25 pipe diameters upstream and 5 to 15 pipe diameters downstream.

For natural gas metering, orifice meters are used mostly in end-use applications, as opposed to a whole-building metering applications, or where space and equipment size are constraints. Orifice meters are commonly used on connection sizes from 0.25 to 4 inches. These meters have accuracies ranging from 0.25 to 2 percent, depending on the fluid, type of orifice, and installation. Orifice meters range in cost from $1,000 to $5,000, with the higher cost systems associated with larger and more accurate meters.

Differential Pressure – Venturi Meter. Similar in function to the orifice meter, the venturi meter takes advantage of the same velocity-pressure relationship (i.e., the change in pressure is proportional to the square of the velocity). In this case, the device causing the change in pressure is not a sharp-edged orifice but rather a section of pipe that gently converges to a small-diameter area (called a throat) before diverging back to the full pipe diameter. Figure 5.5 presents the operation of a typical venturi meter.

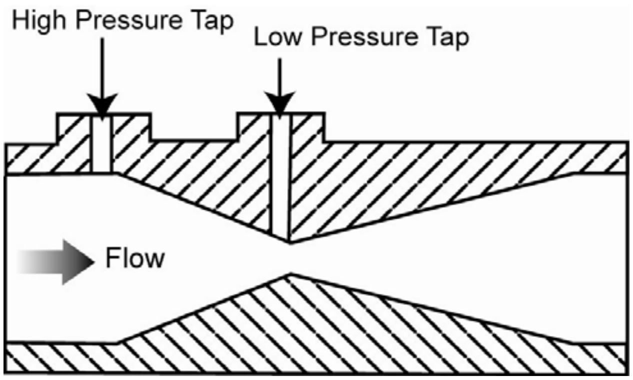

Figure 5.5. Typical Venturi Meter

The benefit of the venturi meter over the orifice meter lies in the reduced pressure loss experienced by the fluid. In situations where the cost to pump a fluid is high, this benefit can represent a significant savings over the life of the system. An additional benefit of the venturi meter is its durability – it does not have the "sharp edge" profile of the orifice meter; therefore, it does not suffer from potential erosion issues and has a greater ability to accurately meter contaminated or non-homogeneous fluids. As with orifice plate meters, venturi meters are used mostly in specialty natural gas applications where size, space, and/or accuracy dictate their use.

Venturi meters are used mostly in specialty natural gas applications where size, space, and/or accuracy dictate their use.

Venturi meters can be used on connection sizes ranging from 0.25 to 4 inches and have accuracies in the range of 0.25 to 2.0 percent, depending on fluid type and installation. Venturi meters can cost from $1,000 to $5,000.

Differential Pressure – Annubar Meter. The annubar flow meter (a variation of the simple pitot tube) also takes advantage of the velocity-pressure relationship of flowing fluids. In this case, the device causing the change in pressure is a pipe inserted into the natural gas flow. Contained within this pipe are two smaller tubes with holes or ports evenly spaced along the length. Figure 5.6 presents the components of the annubar flow meter. When properly installed, one tube faces directly upstream and one downstream. These tubes and ports become the pressure detection points for the meter; the upstream-facing ports measure the flowing pressure (i.e., velocity pressure) and the downstream port measures the static pressure. Using these measured pressure values and the previously mentioned pressure-flow relationship, the flow rate is calculated.

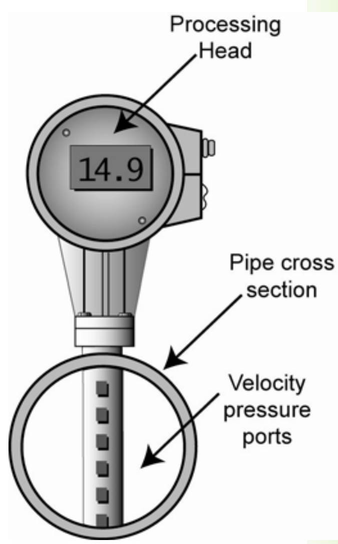

Figure 5.6. Typical Annubar Meter

Annubar flow meters have a turndown ratio of up to 10:1 and are relatively easy to install. These meters can make measurements on pipe sizes from 2 to 100 inches to an accuracy of 2 percent. Annubar meters can cost between $1,000 to $3,000, depending on size and accuracy.

5.3.2.3 Velocity Meters

Velocity meters determine fluid flow by measuring a representation of the flow directly. Because the fluid's velocity is measured (i.e., not the square-root relationship to determine velocity as with differential pressure meters), velocity meters can have better accuracy and usually have better turndown ratios than other meter types.

Velocity – Turbine Meter. Turbine meters operate as their name implies. A multi-blade impellor-like device is located in, and horizontal to, the fluid stream. As the fluid passes through the turbine blades, the impellor rotates at a speed related to the fluid's velocity. Blade speed can be sensed by a number of techniques including magnetic pick-up, mechanical gears, and photocell. The pulses generated as a result of blade rotation are directly proportional to fluid velocity, and hence, flow rate. Figure 5.7 details the components of a typical turbine meter. It should be noted that there are a variety of turbine designs and mounting configurations, of which Figure 5.7 highlights the concept.

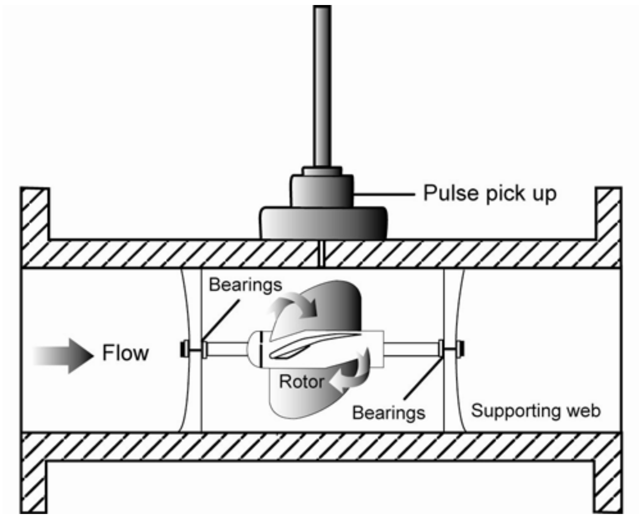

Figure 5.7. Typical Turbine Meter

Because the turbine meter has mechanical elements in the fluid stream, turbine meters can be susceptible to wear and resulting inaccuracies. Of particular concern are the bearings that, if exposed to corrosive or contaminated fluids, can quickly wear and result in inaccuracy. The natural gas applications for turbine meters are typically for larger industrial metering functions. Turbine meters are used on connection sizes ranging from 2 to 20 inches and have accuracies in the range of 0.5 to 1.0 percent, depending on fluid type and installation. Turbine meters can cost from $500 to $5,000, depending on size.

Velocity – Vortex Shedding Meter. A vortex shedding meter senses flow disturbances around a stationary body (called a bluff body) positioned in the middle of the fluid stream. As fluid flows around the bluff body, eddies or vorticies are created downstream; the frequencies of these vorticies are directly proportional to the fluid velocity. Figure 5.8 presents the typical vortex shedding meter.

As the vorticies are developed along the bluff body, they grow and are detached – it is this detachment that is electronically sensed and totalized. Because the vortex shedding meter has no moving parts, it is a very reliable method of natural gas measurement. As with the other non-positive displacement meters, the vortex shedding meter is used in very specific natural gas applications. Vortex shedding meters can be used on connection sizes of 1 to 12 inches and have accuracies in the 1 to 2 percent range. Vortex shedding meters are relatively expensive, typically costing between $4,000 and $6,000.

The natural gas applications for turbine meters are typically for larger industrial metering functions.

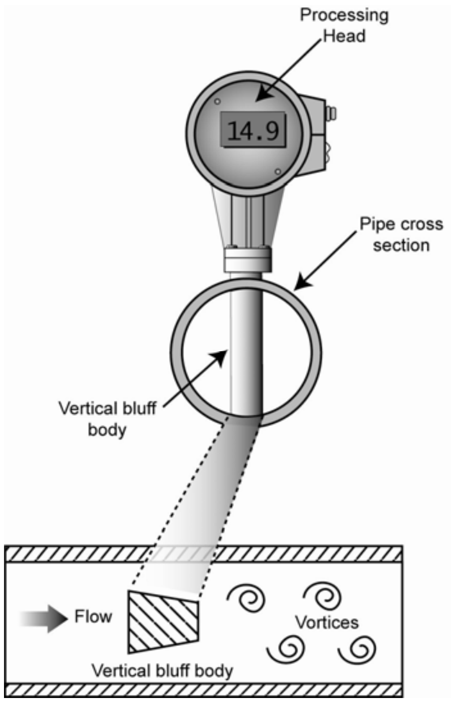

Figure 5.8. Typical Vortex Shedding Meter

5.3.3 Recording Intervals

Due to the way natural gas is purchased and used, the data-recording interval is not as critical as it is for electricity. However, an ability to record gas use at least hourly, if not every 15 minutes, can afford some diagnostic capabilities. One such capability would be to diagnose the short-cycling of a boiler or other gas-using device; if the recording interval were too long, this frequent (and inefficient) on/off boiler operation would be masked in the longer recording interval. The best capability is to be able to modify the interval (at times to a shorter more refined interval) for temporary diagnostics and then return the setting to the longer more manageable interval.

5.3.4 Natural Gas Meter Maintenance

Depending on the meter technology, installation, and quality of gas delivered, natural gas meters generally require limited maintenance. Procedures followed should be those as recommended by the manufacturer. Pending their availability, below are some general maintenance guidelines, presented by meter technology.

Depending on the meter technology, installation, and quality of gas delivered, natural gas meters generally require limited maintenance.

Positive Displacement Meter

Monthly Inspections

- All connections for gas leakage
- Noisy operation internal to meter
- Consistent and smooth register operation
- General meter cleanliness

Annual Inspections

- Calibration according to manufacturer's recommendation or if trended data indicate miscalibration.

Differential Pressure Meter

Monthly Inspections

- All connections for gas leakage
- Abnormally loud or discontinuous sounds internal to meter
- Check for properly connected and sealed pressure taps
- General meter cleanliness

Annual Inspections

- Check orifice diameter and edges for wear, roughness, or material buildup
- Check venturi for cleanliness and corrosion at throat. Clean and smooth all internal surfaces.
- Check for well-connected and sealed pressure taps
- Calibration of differential pressure sensors/transmitters according to manufacturer's recommendation or if trended data indicate miscalibration.

Velocity Meter

Monthly Inspections

- All connections for gas leakage
- Abnormally loud or discontinuous sounds internal to meter
- General meter cleanliness

Annual Inspections

- Impeller blades should be checked for wear or damage
- Impeller bearings should be checked for wear
- Calibration of velocity meter according to manufacturer's recommendation or if trended data indicate miscalibration.

5.3.5 Natural Gas Metering Data Output/Communications Considerations

At the whole-building level, where positive displacement diaphragm and rotary meters are the most common, the typical data output are calibrated pulses. While other output options are available (4 to 20 milliamp, 0-5 volt, Modbus, etc.), calibrated pulses are the most common and relatively easy to work with. Chapter 6 addresses in more detail the different output and communications options.

When specifying the natural gas flow meter, the pulse calibration is a critical parameter. Important in this specification is understanding the range of expected flow and necessary resolution of output. There are situations where too high of a pulse count (i.e., too high of a frequency) can result in saturation of the data logger or other collection device. A saturation condition usually results in loss of data and erroneous pulse counts. Therefore, meter and data logger vendors should be consulted when determining the appropriate pulse count and calibration.

When specifying the natural gas flow meter, the pulse calibration is a critical parameter.

5.3.6 Natural Gas Meter Specification Considerations

- Determine expected range of gas flows.
- Determine the accuracy requirements over the flow range – this will help define the necessary turndown ratio.
- Identify any physical installation requirements for meter location, straight lengths of piping, available communications, etc.
- Communication interoperatability – consider standardization on communication between meters and other data acquisition systems.
- Specification considerations – at the outset, consider a formal specification development of future additions to ensure future compatibility.
- Data processing – how will the collected data be processed? Does the metering equipment vendor offer this function/service? Do not overlook the effort it will take to create a process to collect, store, and archive the data.
- Facility staff buy-in – make certain those staff that will be installing, maintaining, and most importantly, using the data have a voice in meter selection.

5.3.7 Natural Gas Meter Selection Criteria

Table 5.1 presents some of the more common natural gas metering technologies and key criteria for selection decisions (Sullivan et al. 2004; Carbon Trust 2005).

Table 5.1. Common Natural Gas Metering Technologies and Key Criteria

Criteria	Positive Displace-ment	Orifice	Venturi	Annubar	Turbine	Vortex Shedding
Accuracy	Good	Moderate	Good	Good	Good	Good
Turndown Ratio	10:1	<5:1	< 5:1	10:1	10:1	20:1
Repeatability	Good	Good	Good	Very Good	Low	Very good
Installation Ease	Easy	Easy	Moderate	Easy	Challenging	Moderate
Pressure loss	Medium	Moderate	Low	Low	Moderate	Low
Recalibration Needs	Infrequent	Frequent	Infrequent	Infrequent	Frequent	Infrequent
Capital Cost	Low	Low	Moderate	Low	Moderate	Moderate
Installed Cost	Moderate	Low	Moderate	Low	Moderate	Moderate
Maintenance Cost	Low	High	Moderate	Low	Moderate	Low

Do not overlook the effort it will take to create a process to collect, store, and archive the metering data.

5.3.8 References

Carbon Trust. 2005. *Good Practices Guide: Reducing Energy Consumption Costs by Steam Metering*. Available at: http://www.carbontrust.co.uk/Publications/

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Sullivan GP, R Pugh, AP Melendez, and WD Hunt. 2004. *O&M Best Practices: A Guide to Achieving Operational Efficiency, Release 2.0*. PNNL-14788, prepared by Pacific Northwest National Laboratory for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/operations_maintenance/om_bpguide.html

5.4 Fluid Metering – Steam

5.4.1 Introduction

When compared to other liquid flow metering, the metering of steam flow presents one of the most challenging metering scenarios. Most steam meters measure a volumetric flow of the steam and, unless this is done carefully, the physical properties of steam will impair the ability to measure and define a volumetric flow rate accurately.

Steam is a defined as a compressible fluid; therefore, a reduction in pressure results in a reduction in density and vice versa. There is a similar relationship with temperature. While the temperature and pressure in steam lines can be relatively constant, in most applications, this is not the case. Changes in the system's dynamics, control system operation and instrument calibration can result in considerable differences between actual pressure/temperature and a meter's design parameters. Therefore, accurate steam flow measurement generally requires the measurement of the fluid's temperature and pressure, in addition to flow. This information is transmitted to an electronic device (either internal or external to the flow meter electronics) and the flow rate is corrected (or compensated) based on actual fluid conditions.

The temperatures associated with steam flow measurement are often quite high and can affect the accuracy and longevity of metering electronics.

Besides the meter accuracy issues relating to pressure and temperature, additional steam properties add to the difficulties experienced in steam flow measurement. The temperatures associated with steam flow measurement are often quite high. These temperatures can affect the accuracy and longevity of metering electronics. Some metering technologies utilized close tolerance moving parts that can be affected by moisture or impurities in the steam. Improperly designed or installed components can result in steam system leakage and impact plant safety. The erosive nature of poor-quality steam can damage steam flow sensing elements and lead to inaccuracies and/or device failure. These differences between steam flow metering and that of other fluid flow metering increase the importance of proper metering design, selection, and installation.

Finally, the challenges of metering steam can be somewhat simplified by instead measuring the condensed steam – the so-called condensate. The metering of condensate (i.e., high-temperature hot water) is a well-accepted practice, often less expensive and more reliable than steam metering. However, depending on the application, inherent inaccuracies in condensate metering stem from unaccounted for system steam losses. These losses are often difficult to find and quantify and thus affect condensate measurement accuracy.

5.4.2 Steam Metering Technologies

In general, measurement of the volumetric flow rate of a closed fluid system is a calculated or inferred value based on the simple relationship of velocity and area. A fluid's volume flow rate is equal to the product of the fluid's velocity and the

Two of the more common differential pressure devices are the orifice meter and the annubar meter.

pipe's cross-section. Since the pipe's cross-sectional area is a known constant, the fluid flow rate can be defined if its velocity can be quantified. This velocity value is then converted into a volumetric and/or mass flow rate. In general, volumetric metering approaches used in steam metering can be broken down into two operating designs: (1) differential pressure and (2) velocity metering technologies (FEMP 2007).

5.4.2.1 Differential Pressure Meters

All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation. Specifically, when an obstruction or orifice is placed in the path of a fluid, the fluid velocity will increase while its pressure decreases. It is this change in pressure that is measured and, via the relationship between pressure drop and the square of the flow, used to calculate the fluid flow rate. Two of the more common differential pressure devices used to measure steam are presented below.

Differential Pressure – Orifice Meter. Historically, the orifice meter is one of the most commonly used meters to measure steam flow. The orifice meter for steam functions identically to that for natural gas flow. The meter has an orifice element that is typically a thin, circular metal disk held between two flanges in the fluid stream. The center of the disk is drilled with a specific-size hole, depending on the expected fluid flow parameters (e.g., pressure and flow range). As the fluid flows through the orifice, the restriction creates a pressure differential upstream and downstream of the orifice proportional to the fluid flow rate. This differential pressure is measured and a flow rate mathematically calculated based on the differential pressure and fluid temperature. Figure 5.9 is a diagram of a typical orifice meter.

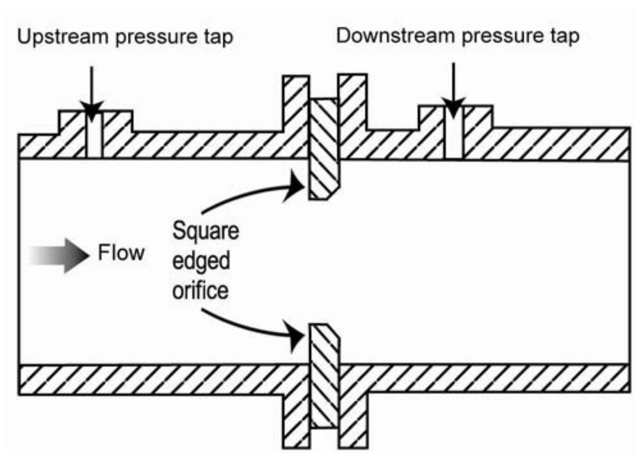


Figure 5.9. Typical Orifice Meter

Orifice meters, by design, develop significant pressure drop within the system. The benefits of this technology (i.e., its relative compactness, its accuracy, and its simple function) should be traded off against the potential decrease pressure drop at the end use.

For steam metering, orifice meters are commonly used to monitor boiler steam production, amounts of steam delivered to a process or tenant, or in mass balance activities for efficiency calculation or trending.

For proper function, the orifice meter requires smooth flow through the orifice. For this to be assured, it requires a significant section of straight pipe both upstream and downstream of the meter. While these lengths may vary by manufacturer, typical lengths fall between 15 to 25 diameters upstream and 5 to 15 diameters downstream. As with most differential pressure meters, the turndown ratio of the orifice plate is usually limited to 5:1; thus, for steam systems with highly variant flow rates, this technology may not be the most accurate choice.

Orifice Plate Advantages/Challenges

Advantages:

- Simplicity and durability
- Good accuracy over moderate turndown ratio
- Relatively inexpensive
- Limited recalibration needs

Challenges:

- Orifice needs to be regularly inspected for shape and size
- When mounted horizontally, dirt and scale can cause blockage/reduced flow through orifice
- Limited turndown

Orifice meters are commonly used on line sizes from 0.25 to 4 inches or larger. These meters have accuracies ranging from 0.25 to 2 percent, depending on the fluid, type of orifice, and installation. Orifice meters range in cost from $1,000 to $5,000, with the higher cost systems associated with larger and more accurate meters.

Differential Pressure – Annubar Meter. The annubar flow meter (a variation of the simple pitot tube) also takes advantage of the velocity-pressure relationship of flowing fluids. In this case, the device causing the change in pressure is a pipe inserted into the steam flow. Contained within this pipe are two smaller tubes with holes or ports evenly spaced along the length. Figure 5.10 presents the components of the annubar flow meter. When properly installed, one tube faces directly upstream and one downstream. These tubes and ports become the pressure detection points for the meter; the upstream-facing ports measure the flowing pressure (i.e., velocity pressure) and the downstream port measures the static pressure. Using these measured pressure values and the previously mentioned pressure-flow relationship, the flow rate is calculated.

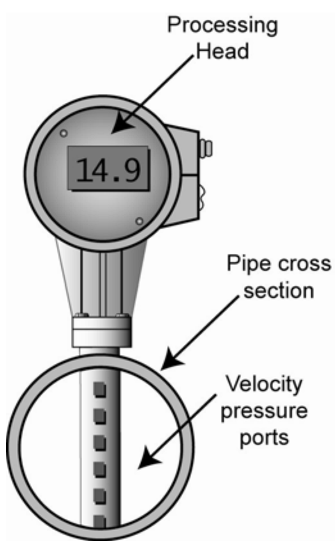


Figure 5.10. Typical Annubar Meter

Annubar Flow Meter Advantages/Challenges

Advantages:
- Limited resistance to flow
- Good accuracy and repeatability
- Lower installation cost – particularly on larger pipe diameters
- Expanded turndown ratio.

Challenges:
- Installation needs proper lengths of pipe for accurate measurements.

Annubar flow meters have a turndown ratio of up to 10:1 and are relatively easy to install. These meters can make measurements on pipe sizes from 2 to 100 inches to an accuracy of 2 percent. Accuracy will vary by installation and requires strict adherence to manufacturer's requirements on straight-pipe-lengths upstream and downstream of the meter. Annubar meters can cost between $1,000 to $3,000, depending on size and accuracy.

5.4.2.2 Velocity Meters

The second general category of steam flow measurement employs the velocity of the steam as the measurement metric. Velocity meters take advantage of the linear relationship between fluid velocity and flow. The two main type of velocity meters for steam flow, turbine and vortex shedding, both sense some flow characteristic directly proportional to the fluid's velocity. In the case of the turbine meter, it is the velocity of the turbine, in the case of the vortex meter, it is the generation frequency of vorticies. Both meter types are described below relative to their steam applications.

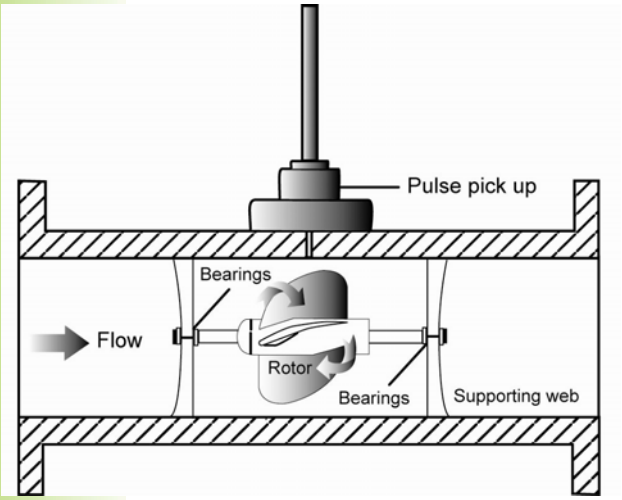


Figure 5.11. Typical Turbine Meter

Velocity – Turbine Meter. The turbine meter for steam flow employs a multi-blade impellor-like device is located in, and horizontal to, the fluid stream. As the fluid passes through the turbine blades, the impellor rotates at a speed related to the fluid's velocity. Blade speed can be sensed by a number of techniques including magnetic pick-up, mechanical gears, and photocell. The pulses generated as a result of blade rotation are directly proportional to fluid velocity, and, hence, flow rate. Figure 5.11 details the components of a typical turbine meter. It should be noted that there are a variety of turbine designs and mounting configurations, of which Figure 5.11 highlights the concept.

Because the turbine meter has mechanical elements in the fluid stream, these meters can be susceptible to wear and resulting inaccuracies. Of particular concern are the bearings that, if exposed to corrosive or contaminated steam flows, can quickly wear and result in inaccuracy. The steam applications for turbine meters are typically larger industrial metering functions. As with the orifice meter, the proper function the turbine meter requires smooth flow. For this to be assured, the meter requires a significant section of straight pipe for upstream and downstream of the meter. While these lengths may vary by manufacturer, typical lengths fall between 15 to 25 diameters upstream and 5 to 15 downstream.

Turbine meters are used on line sizes ranging from 2 to 20 inches and have accuracies in the range of 0.5 to 1.0 percent depending on fluid type and installation and turndown ratio of up to 10:1. Turbine meters can cost from $500 to $5,000, depending on size.

Velocity – Vortex Shedding Meter. The steam vortex shedding meter senses flow disturbances around a stationary body (called a bluff body) positioned in the middle of the fluid stream. As the fluid, steam in this case, flows around the bluff body, eddies or vorticies are created downstream. A sensing element, usually a piezo-electric element, detects the frequencies of these vorticies, which are directly proportional to the fluid velocity. Figure 5.12 presents the typical vortex shedding meter. As the vorticies are developed along the bluff body, they grow and are detached – it is this detachment that is sensed and totalized.

Because the vortex shedding meter has no moving parts, it is a very reliable method of steam-flow measurement. In addition, because the meter

Turbine Meter Advantages/Challenges

Advantages:
- Good accuracy over larger turndown ratio.

Challenges:
- Impeller bearing wear
- Rotor blade erosion
- Recalibration to adjust for bearing and blade wear

Vortex Meter Advantages/Challenges

Advantages:
- Good accuracy over large turndown ratio
- Higher reliability owing to the lack of any moving parts
- With high-quality steam, recalibration need is negated

Challenges:
- Meter needs to be isolated from mechanical vibration
- Longer lengths of straight pipe for accurate operation

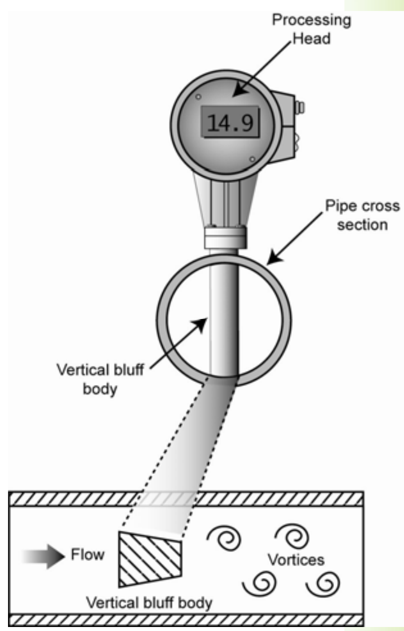


Figure 5.12. Typical Vortex Shedding Meter

measures flow directly (versus the exponential relationship of differential meters) a higher turndown ratio can be achieved – on the order of 20:1.

Vortex shedding meters can be used on line sizes of 1 to 12 inches and has accuracies in the 1 to 2 percent range. Vortex shedding meters are relatively expensive, typically costing between $4,000 and $6,000.

5.4.3 Recording Intervals

Due to the way steam is generated and/or purchased and used, the data-recording interval is not as critical as it is for electricity. However, an ability to record steam use at least hourly, if not every 15 minutes (or less), can afford some diagnostic capabilities. One such capability would be to diagnose excessive line loss or steam leakage. In this case, a detailed recording of high off-hours (low-load) steam production and frequency could be very diagnostic. If the recording interval were too long, these losses may be masked in the longer recording interval. The best capability is to be able to modify the interval (at times to a shorter more refined interval) for temporary diagnostics and then return the setting to the longer more manageable interval.

Depending on the meter technology, installation, and quality of steam generated, steam meters can require a significant amount of maintenance attention.

5.4.4 Steam Meter Maintenance

Depending on the meter technology, installation, and quality of steam generated, steam meters can require a significant amount of maintenance attention. Procedures followed should be those as recommended by the manufacturer. Pending their availability, below are some general maintenance guidelines presented by meter technology.

Differential Pressure Meters

Monthly Inspections
- All connections for steam leakage
- Abnormally loud or discontinuous sounds internal to meter
- Check for properly connected and sealed pressure taps
- General meter cleanliness

Annual Inspections
- Check orifice diameter and edges for wear, roughness, or material buildup
- Check pressure parts for wear, roughness, or material buildup
- Check for properly connected and sealed pressure taps
- Calibration of differential pressure sensors/transmitters according to manufacturer's recommendation or if trended data indicate miscalibration.

Velocity Meters

Monthly Inspections
- All connections for steam leakage
- Abnormally loud or discontinuous sounds internal to meter
- General meter cleanliness

Annual Inspections
- Impeller blades should be checked for wear or damage
- Impeller bearings should be checked for wear
- Calibration of velocity meter according to manufacturer's recommendation or if trended data indicate miscalibration.

5.4.5 Steam Metering Data Output/Communications Options

The most common outputs of steam metering devices are scalable analog signals of either 4 to 20 mA or 0 to 5 volts dc. These outputs typically are collected and processed using a flow computer/analysis devise integral to the meter. This device takes the measurement signals (pressure, differential pressure, and temperature) and convert these to a compensated flow rate.

When specifying a steam meter, the flow computer/analysis device is typically an option with some array of alternatives for analysis and presentation. The output of the flow computer/analysis device is typically a scalable signal or pulse that can be transferred to a data acquisition/logger system for collection and further analysis or trending. Chapter 6 addresses in more detail the different output and communications options.

Staff who install, maintain, and use the data should have a voice in meter selection.

5.4.6 Steam Meter Specification Considerations

- Determine generated steam characteristics (i.e., dry, wet, saturated, and the corresponding temperatures) – this will make sure compatible meters are considered.

- Determine expected range of steam flows.

- Determine the accuracy requirements over the flow range – this will help define the necessary turndown ratio.

- Communication interoperatability – consider standardization on communication between meters and other data acquisition systems.

- Specification considerations – at the outset, consider a formal specification development so future additions to ensure future compatibility.

- Data processing – how will the collected data be processed? Does the metering equipment vendor offer this function/service? Do not overlook the effort it will take to create a process to collect, store, and archive the data.

- Facility staff buy-in – make certain those staff that will be installing, maintaining, and most importantly, using the data have a voice in meter selection.

5.4.7 Steam Meter Selection Criteria

Table 5.2 presents some of the more common steam metering technologies and key criteria for selection decisions (Sullivan et al. 2004; Carbon Trust 2005).

The most common outputs of steam metering devices are scalable analog signals.

Table 5.2. Common Steam Metering Technologies and Key Criteria

Criteria	Orifice	Annubar	Turbine	Vortex Shedding
Accuracy	Moderate	Good	Good	Good
Turndown Ration	<5:1	5:1	10:1	20:1
Repeatability	Good	Good	Low	Very good
Installation Ease	Easy	Easy	Challenging	Moderate
Pressure loss	Moderate	Low	Moderate	Low
Recalibration Needs	Frequent	Infrequent	Frequent	Infrequent
Capital Cost	Low	Low	Moderate	Moderate
Installed Cost	Low	Low	Moderate	Moderate
Maintenance Cost	High	Low	Moderate	Low

5.4.8 References

Carbon Trust. 2005. *Good Practices Guide: Reducing Energy Consumption Costs by Steam Metering*. Available at: http://www.carbontrust.co.uk/Publications/

FEMP. 2007. *FEMP Metering Training Course Session 2: Metering Technologies, Communications, and Data Storage*. April 4, 2005. Available at: http://eere.pnl.gov/femp/metering_webcast.stm

Sullivan GP, R Pugh, AP Melendez, and WD Hunt. 2004. *O&M Best Practices: A Guide to Achieving Operational Efficiency, Release 2.0*. PNNL-14788, prepared by Pacific Northwest National Laboratory for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/operations_maintenance/om_bpguide.html

5.5 Fluid Metering – Potable Water

5.5.1 Introduction

The physical properties associated with potable water lend themselves to a wide variety of metering technologies. The lack of high temperature and/or two-phase flow allows use of metering technologies not suitable for other applications (e.g., steam or high temperature hot water). Because the metering of potable water is generally concerned with the quantification of flow volume, and not energy content, lower-cost metering options can be used. The specific metering option chosen will depend on a number of factors including, but not limited to, current design, budget, accuracy requirements, minimum flow, range of flow, and maximum flow.

5.5.2 Potable Water Metering Technologies

In general, measurement of the volumetric flow rate of a closed fluid system is a calculated or inferred value based on the simple relationship of velocity and area. A fluid's volume flow rate is equal to the product of the fluids velocity and the pipe's cross-section. Since the pipe's cross-sectional area is a known constant, the fluid flow rate can be defined if its velocity can be quantified. Some meter styles measure fluid flow directly by incrementally moving the fluid through a known volume (positive displacement meters). These volumetric increments are counted by a variety of mechanical/electronic approaches and the flow rate converted to the desired unit (e.g., gpm). In general, volumetric water metering designs can be broken down into three general operating designs: (1) positive displacement, (2) differential pressure, and (3) velocity (FEMP 2007). Some meters have been specifically designed for applications generally falling outside those required for general building utility metering needs, for instance, mass meters like coriolis and thermal or electromagnetic meters. The balance of this section will focus on the three operating designs mentioned above.

Because the metering of potable water is generally concerned with the quantification of flow volume, and not energy content, lower-cost metering options can be utilized.

5.5.2.1 Positive Displacement Meters

As the name implies, a positive displacement meter functions by the action of the fluid physically displacing the measuring mechanism. Several different designs exist that determine water flow rate based on how fast a known volume of water enters and exits the meter. Nutating-disk, oval-gear, piston, and rotary-vane are all styles of positive displacement meters. Of relevancy to potable water measurement, the predominant positive displacement technology is the nutating-disk flow meter.

Positive Displacement – Nutating-Disk Meter. Because of its ease of installation and relatively low cost, nutating-disk meters are the most common potable water metering devices for up to 3-inch connections.

The nutating disk meter consists of a disk mounted on a spherically shaped head and housed in a measuring chamber. As the fluid flows through the meter passing on either side of the disk, it imparts a rocking or nutating motion to the disk. This motion is then transferred to a shaft mounted perpendicular to the disk. It is this shaft that traces out a circular motion – transferring this action to a register that records flow.

For potable water metering, nutating disk meters are typically found at the service entrances to buildings and homes. These meters are most often used on pipe sizes up to 3 inches and have an accuracy in the range of 0.5 to 1.0 percent. Nutating disk meters cost from $50 to $400, depending on the size.

5.5.2.2 Differential Pressure Meters

All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation.

All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation. Specifically, when an obstruction or orifice is placed in the path of a fluid, the fluid velocity will increase while its pressure decreases. It is this change in pressure that is measured and, via the relationship between pressure drop and the square of the flow, used to calculate the fluid flow rate. There are a variety of differential pressure devices useful for water metering, three of the more common devices are described below.

Differential Pressure – Orifice Meter. Although various style orifices are manufactured, the basic design and operation remain the same. The orifice element is typically a thin, circular metal disk held between two flanges in the fluid stream. The center of the disk is drilled with a specific-size hole, depending on the expected fluid flow parameters (e.g., pressure and flow range). As the fluid flows through the orifice, the restriction creates a pressure differential upstream and downstream of the orifice proportional to the fluid flow rate. This differential pressure is measured and a flow rate mathematically calculated based on the differential pressure and fluid temperature. Figure 5.13 presents a diagram of a typical orifice meter.

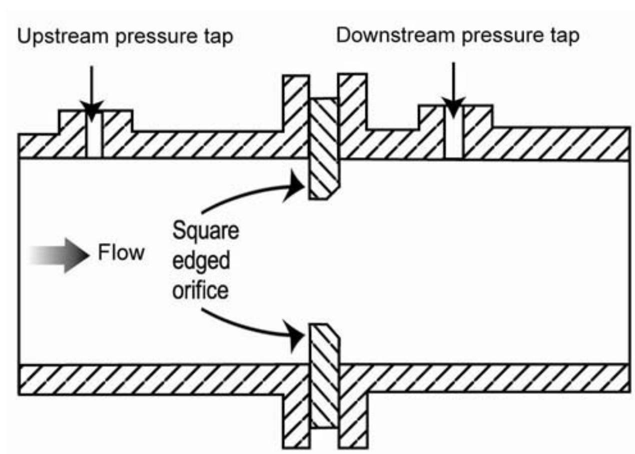


Figure 5.13. Typical Orifice Meter

Orifice meters, by design, develop significant pressure drop within the system. The benefits of this technology (i.e., its relative compactness, its accuracy, and its simple function) should be traded off against the potential decrease pressure drop at the end use.

Orifice meters are commonly used on line sizes from 0.25 to 4 inches. These meters have accuracies ranging from 0.25 to 2 percent, depending on the fluid, type of orifice, and installation. Orifice meters range in cost from $1,000 to $5,000, with the higher cost systems associated with larger and more accurate meters.

Differential Pressure – Venturi Meter. Similar in function to the orifice meter, the venturi meter takes advantage of the same velocity-pressure relationship (change in pressure is proportional to the square of the velocity). In this case, the device causing the change in pressure is not a sharp-edged orifice but rather a section of pipe that gently converges to a small-diameter area (called a throat) before diverging back to the full pipe diameter. Figure 5.14 presents the operation of a typical venturi meter.

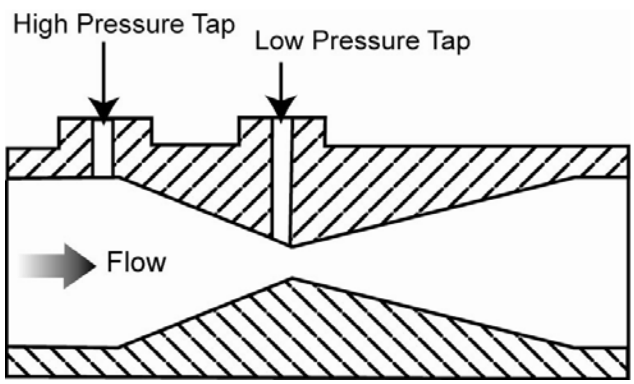


Figure 5.14. Typical Venturi Meter

The benefit of the venturi meter over the orifice meter lies in the reduced pressure loss experienced by the fluid.

The benefit of the venturi meter over the orifice meter lies in the reduced pressure loss experienced by the fluid. In situations where the cost to pump a fluid is high, this benefit can represent a significant savings over the life of the system. An additional benefit of the venture meter is its durability – it does not have the "sharp edge" profile of the orifice meter; therefore, it does not suffer from potential erosion issues and has a greater ability to accurately meter contaminated on non-homogeneous fluids. As with orifice plate meters, venturi meters are used mostly in specialty potable water applications where size, space, and/or accuracy dictate their use.

Venturi meters can be used on connection sizes ranging from 0.25 to 4 inches and have accuracies in the range of 0.25 to 2.0 percent, depending on fluid type and installation. Venturi meters can cost from $1,000 to $5,000.

Because the turbine meter has mechanical elements in the fluid stream, these meters can be susceptible to wear and resulting inaccuracies.

5.5.2.3 Velocity Meters

Another means to determine fluid flow is by a technique that directly relates to the fluid's velocity. Velocity meters determine fluid flow by measuring a representation of the flow directly. Because the fluid's velocity is measured (i.e., not the square-root relationship to determine velocity as with differential pressure meters), velocity meters can have better accuracy and usually have better turndown ratios than other meter types.

Velocity – Turbine Meter. Turbine meters operate as their name implies. A multi-blade impellor-like device is located in, and horizontal to, the fluid stream. As the fluid passes through the turbine blades, the impellor rotates at a speed related to the fluid's velocity. Blade speed can be sensed by a number of techniques including magnetic pick-up, mechanical gears, and photocell. The pulses generated as a result of blade rotation are directly proportional to fluid velocity, and hence flow rate. Figure 5.15 details the components of a typical turbine meter. It should be noted that there are a variety of turbine designs and mounting configurations, of which Figure 5.15 highlights the concept.

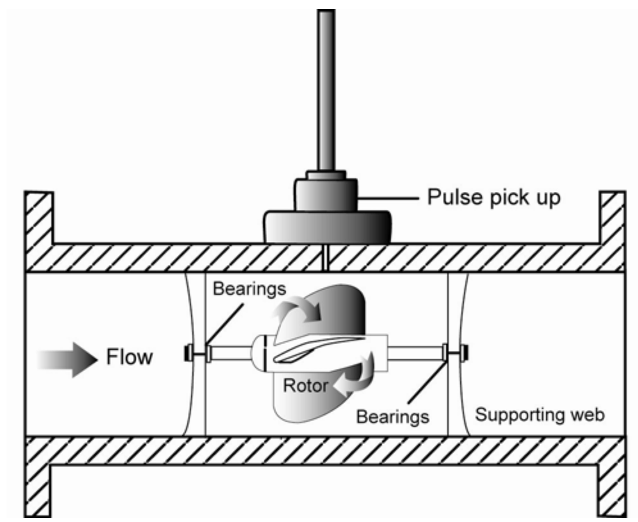


Figure 5.15. Typical Turbine Meter

Because the turbine meter has mechanical elements in the fluid stream, these meters can be susceptible to wear and resulting inaccuracies. Of particular concern are the bearings that, if exposed to corrosive or contaminated fluids, can quickly wear and result in inaccuracy. The potable water applications for turbine meters are typically for larger industrial metering functions. Turbine meters are used on connection sizes ranging from 2 to 20 inches and have accuracies in the range of 0.5 to 1.0 percent, depending on fluid type and installation. Turbine meters can cost from $500 to $5,000, depending on size.

Velocity – Vortex Shedding Meter. A vortex shedding meter senses flow disturbances around a stationary body (called a bluff body) positioned in the middle of the fluid stream. As fluid flows around the bluff body, eddies or vorticies are created downstream; the frequencies of these vorticies are directly proportional to the fluid velocity. Figure 5.16 presents the typical vortex shedding meter.

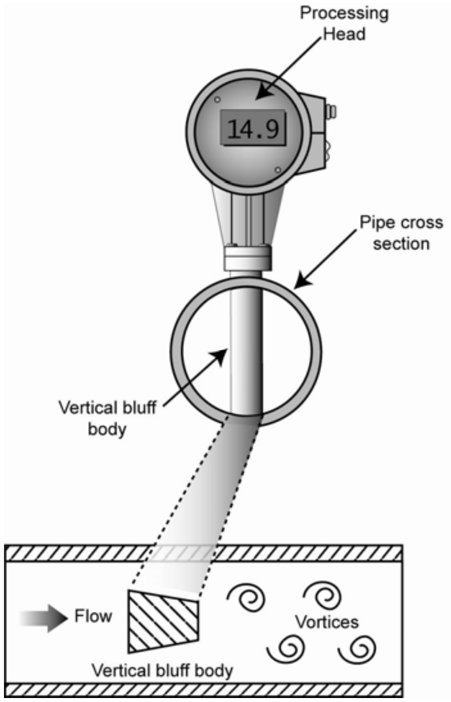


Figure 5.16. Typical Vortex Shedding Meter

As the vorticies are developed along the bluff body, they grow and are detached – it is this detachment that is electronically sensed and totalized. Because the vortex shedding meter has no moving parts, it is a very reliable method of potable water measurement. As with the other non-positive displacement meters, the vortex shedding meter is used in very specific potable water applications. Vortex shedding meters can be used on connection sizes of 1 to 12 inches and have accuracies in the 1 to 2 percent range. Vortex shedding meters are relatively expensive, typically costing between $4,000 and $6,000.

Vortex shedding meters can be used on connection sizes of 1 to 12 inches and have accuracies in the 1 to 2 percent range.

Velocity – Ultrasonic Meters. Ultrasonic meters function through the basic relationship between the velocity of a fluid and its accompanying frequency shift – also know as the Doppler effect. One of the most attractive aspects of ultrasonic flow meters is they are completely non-intrusive. That is, this technology does not require any permanent modifications or penetrations to piping or disruption of service for installation. All ultrasonic meters mount on the outside of the piping and can be used as both temporary and permanent metering.

There are two styles of ultrasonic flow meters available: Doppler meters and transit time meters. The Doppler meters function by measuring the frequency shift of the moving fluid to calculate flow. This technology works best when the fluid has suspended solids, bubbles, or other particles to reflect the ultrasonic signal. Figure 5.17 presents the function of the Doppler ultrasonic meter.

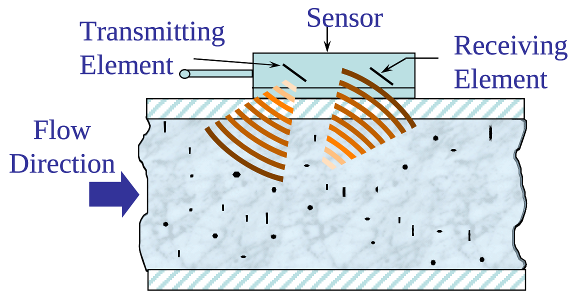


Figure 5.17. Doppler Ultrasonic Flow Meter

The transit time meter makes use of a transmitter and receiver mounted on opposite sides of the pipe. As fluid moves through the system, the first transducer sends a signal and the second receives it. The time it takes for the signal to arrive is proportionate to the flow rate. Different from the Doppler meter, the transit time meter needs clean and viscous liquids for best accuracy. Figure 5.18 presents the function of the transit time ultrasonic meter.

Due to the way water is usually purchased and used, the data-recording interval is not as critical as it is for electricity.

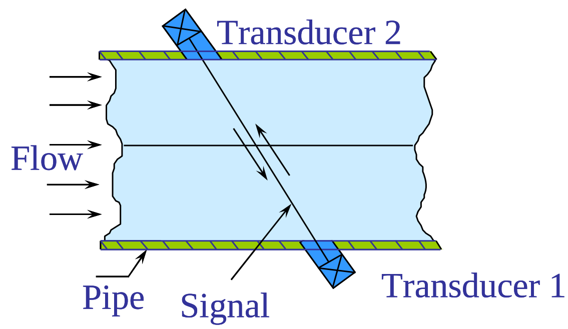


Figure 5.18. Transit Time Ultrasonic Flow Meter

Because ultrasonic meters have no moving parts, they are very reliable. These meters can be used on connection sizes up to 20 inches or larger and have accuracies ranging from 1 to 5 percent. Both types of ultrasonic meters are relatively expensive, costing between $2,000 and $7,000.

5.5.3 Recording Intervals

Due to the way water is usually purchased and used, the data-recording interval is not as critical as it is for electricity. However, an ability to record water use at least hourly, if not every 15 minutes, can afford some diagnostic capabilities. One such capability would be to diagnose proper water flows and volumes based on known water uses. Another excellent use is leak detection where higher resolution (and short intervals) can be very diagnostic. The best capability is to be able to modify the interval (at times to a shorter more refined interval) for temporary diagnostics and then return the setting to the longer more manageable interval.

5.5.4 Potable Water Meter Maintenance

Depending on the meter technology, installation, and quality of water delivered, potable water meters generally require limited maintenance. Procedures followed should be those as recommended by the manufacturer. Pending their availability, below are some general maintenance guidelines presented by meter technology.

Positive Displacement Meter

Monthly Inspections
- All connections for water leakage
- Noisy operation internal to meter
- Consistent and smooth register operation
- General meter cleanliness

Annual Inspections
- Calibration according to manufacturer’s recommendation of if trended data indicate miscalibration.

Differential Pressure Meter

Monthly Inspections
- All connections for water leakage
- Abnormally loud or discontinuous sounds internal to meter
- Check for properly connected and sealed pressure taps
- General meter cleanliness

Annual Inspections
- Check orifice diameter and edges for wear, roughness, or material buildup
- Check venturi for cleanliness and corrosion at throat. Clean and smooth all internal surfaces.
- Check for well connected and sealed pressure taps
- Calibration of differential pressure sensors/transmitters according to manufacturer’s recommendation or if trended data indicate miscalibration.

Velocity Meter

Monthly Inspections
- All connections for water leakage
- Abnormally loud or discontinuous sounds internal to meter
- General meter cleanliness

Depending on the meter technology, installation, and quality of water delivered, potable water meters generally require limited maintenance.

Annual Inspections

- Impeller blades should be checked for wear or damage
- Impeller bearings should be checked for wear
- Calibration of velocity meter according to manufacturer's recommendation or if trended data indicate miscalibration.

Ultrasonic Meter

Monthly Inspections

- Transducer positions and attachment to piping
- Cleanliness of transducer/piping interface
- Verification of piping isolation (i.e., no vibration in metering section)
- General meter cleanliness

Annual Inspections

- Calibration of meter according to manufacturer's recommendation or if trended data indicate miscalibration.

5.5.5 Potable Water Metering Data Output/Communications Considerations

When specifying the potable water flow meter, the pulse calibration is a critical parameter.

At the whole-building level, where nutating disk meters are the most common, the typical data output is calibrated pulses. While other output options are available (4 to 20 milliamp, 0 to 5 volt, Modbus, etc.), calibrated pulses are the most common and relatively easy to work with. Chapter 6 addresses in more detail the different output and communications options.

When specifying the potable water flow meter, the pulse calibration is a critical parameter. Important in this specification is an understanding of the range of expected flow and necessary resolution of output. There are situations where too high of a pulse count (i.e., too high of a frequency) can result in saturation of the data logger or other collection device. A saturation condition usually results in loss of data and erroneous pulse counts; therefore, it needs to be avoided. Meter and data logger vendors should be consulted when determining the appropriate pulse count and calibration.

5.5.6 Potable Water Meter Selection Considerations

- Determine expected range of potable water flows and pipe sizes.

- Determine the accuracy requirements over the flow range.

- Identify any physical installation requirements for meter location, straight lengths of piping, available communications, etc.

- Communication interoperatability – consider standardization on communication between meters and other data acquisition systems.

- Specification considerations – at the outset, consider a formal specification development so future additions to ensure future compatibility.

- Data processing – how will the collected data be processed? Does the metering equipment vendor offer this function/service? Do not overlook the effort it will take to create a process to collect, store, and archive the data.

- Facility staff buy-in – make certain those staff that will be installing, maintaining, and most importantly, using the data, have a voice in meter selection.

Determining the accuracy requirements over the flow range is one of the considerations for selecting a meter for potable water.

5.5.7 Potable Water Meter Selection Criteria

Table 5.3 presents some of the more common potable water metering technologies and key criteria for selection decisions (Sullivan et al. 2004, Carbon Trust 2005).

Table 5.3. Common Potable Water Metering Technologies and Key Criteria

Criteria	Positive Displace-ment	Orifice	Venturi	Turbine	Vortex Shedding	Ultrasonic Dop/TT
Accuracy	Good	Moderate	Good	Good	Good	Moderate
Turndown Ratio	10:1	<5:1	< 5:1	10:1	20:1	10:1 / 20:1
Repeatability	Good	Good	Good	Low	Very good	Good
Installation Ease	Easy	Easy	Moderate	Challenging	Moderate	Very easy
Pressure Loss	Medium	Moderate	Low	Moderate	Low	None
Recalibration Needs	Infrequent	Frequent	Infrequent	Frequent	Infrequent	Moderate
Capital Cost	Low	Low	Moderate	Moderate	Moderate	High
Installed Cost	Moderate	Low	Moderate	Moderate	Moderate	Low
Maintenance Cost	Low	High	Moderate	Moderate	Low	Low

5.5.8 References

Carbon Trust. 2005. *Good Practices Guide: Reducing Energy Consumption Costs by Steam Metering*. Available at: http://www.carbontrust.co.uk/Publications/

FEMP. 2007. *FEMP Metering Training Course Session 2: Metering Technologies, Communications, and Data Storage*. April 4, 2005. Available at: http://eere.pnl.gov/femp/metering_webcast.stm

Sullivan GP, R Pugh, AP Melendez, and WD Hunt. 2004. *O&M Best Practices: A Guide to Achieving Operational Efficiency, Release 2.0*. PNNL-14788, prepared by Pacific Northwest National Laboratory for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/operations_maintenance/om_bpguide.html

There are situations where too high of a pulse count can result in saturation of the data logger or other collection device.

5.6 Fluid Metering – High-Temperature Hot Water/Chilled Water

5.6.1 Introduction

Although the flow metering principles remain the same, whether metering hot or chilled water, fluid temperature will affect final meter selection. To ensure the accuracy of most volumetric metering, water temperature must be maintained below saturation temperature related to the fluid pressure. Provided this relationship is maintained, the hardware required to meter volumetric flow rates of hot and cold water changes very little. However, not all flow metering equipment is designed to be used in high-temperature and/or high-pressure environments. Hot water will require selecting metering equipment designed to be used in the application's environmental conditions. Although a common practice in steam metering, compensating flow rates due to fluctuations in pressure and/or temperature is seldom done; pressure/temperature variations only slightly affect the metering accuracy of water if maintained below saturation conditions.

Common applications of high-temperature hot water metering include high-temperature hot water distribution/heating systems and metering of condensate-return systems. Common chilled water metering applications include central chilled water distribution or packaged chiller systems.

Making sure the meter you have selected is applicable for the operating temperature range is critical to its performance and accuracy.

5.6.2 High-Temperature Hot Water/Chilled Water Technologies

High temperature and chilled water metering technologies are consistent with those presented in the previous section (FEMP 2007). However, the one caveat in selecting a meter for a high-temperature environment is verifying the meter is approved to operate in the expected range. Many manufacturers offer products for both standard and high-temperature environments – making sure the meter you have selected is applicable for the operating temperature range is critical to its performance and accuracy.

5.6.2.1 Positive Displacement Meters

As the name implies, a positive displacement meter functions by the action of the fluid physically displacing the measuring mechanism. Several different designs exist that determine water flow rate based on how fast a known volume of water enters and exits the meter. Nutating-disk, oval-gear, piston, and rotary-vane are all styles of positive displacement meters. Of relevancy to high temperature and chilled water measurement, the predominant positive displacement technology is the nutating disk flow meter.

Positive Displacement – Nutating Disk Meter. Because of its ease of installation and relatively low cost, nutating disk meters are the most common of the positive displacement technologies for up to 3-inch connections.

All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation.

The nutating disk meter consists of a disk mounted on a spherically-shaped head and housed in a measuring chamber. As the fluid flows through the meter passing on either side of the disk, it imparts a rocking or nutating motion to the disk. This motion is then transferred to a shaft mounted perpendicular to the disk. It is this shaft that traces out a circular motion – transferring this action to a register that records flow.

These meters are most often used on pipe sizes up to 3 inches and have an accuracy in the range of 0.5 to 1.0 percent. Nutating disk meters cost from $50 to $400 – depending on the size. When considering a nutating disk meter for high-temperature fluids, make certain the meter is rated for the expected temperature range.

5.6.2.2 Differential Pressure Meters

All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation. Specifically, when an obstruction or orifice is placed in the path of a fluid, the fluid velocity will increase while its pressure decreases. It is this change in pressure that is measured and, via the relationship between pressure drop and the square of the flow, used to calculate the fluid flow rate. There are a variety of differential pressure devices useful for high-temperature/chilled water metering; two of the more common devices are described below.

Differential Pressure – Orifice Meter. Although various style orifices are manufactured, the basic design and operation remain the same. The orifice element is typically a thin, circular metal disk held between two flanges in the fluid stream. The center of the disk is drilled with a specific-size hole, depending on the expected fluid flow parameters (e.g., pressure and flow range). As the fluid flows through the orifice, the restriction creates a pressure differential upstream and downstream of the orifice proportional to the fluid flow rate. This differential pressure is measured and a flow rate mathematically calculated based on the differential pressure and fluid temperature. Figure 5.19 presents a diagram of a typical orifice meter.

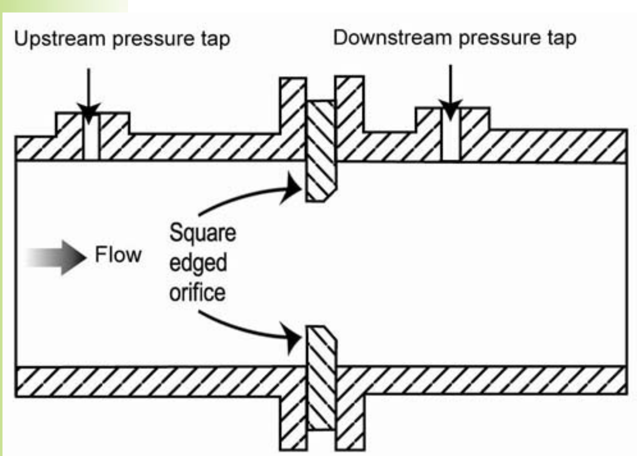


Figure 5.19. Typical Orifice Meter

Orifice meters, by design, develop significant pressure drop within the system. The benefits of this technology (i.e., its relative compactness, its accuracy, and its simple function) should be traded off against the potential decrease pressure drop at the end use.

Orifice meters are commonly used on line sizes from 0.25 to 4 inches. These meters have accuracies ranging from 0.25 to 2 percent depending on the fluid, type of orifice, and installation. Orifice meters range in cost from $1,000 to $5,000, with the higher cost systems associated with larger and more accurate meters.

Differential Pressure – Venturi Meter. Similar in function to the orifice meter, the venturi meter takes advantage of the same velocity-pressure relationship (change in pressure is proportional to the square of the velocity). In this case, the device causing the change in pressure is not a sharp-edged orifice but rather a section of pipe that gently converges to a small diameter area (called a throat) before diverging back to the full pipe diameter. Figure 5.20 presents the operation of a typical venturi meter.

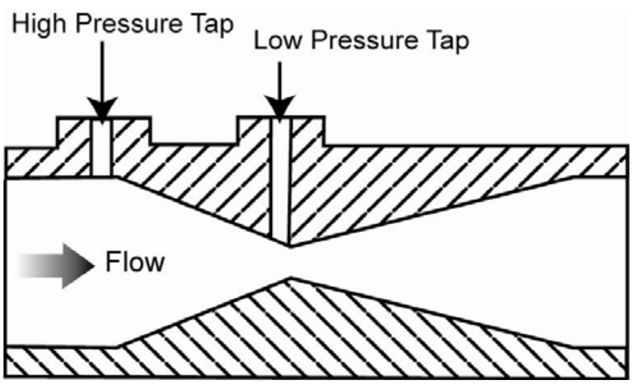


Figure 5.20. Typical Venturi Meter

The benefit of the venturi meter over the orifice meter lies in the reduced pressure loss experienced by the fluid. In situations where the cost to pump a fluid is high, this benefit can represent a significant savings over the life of the system. An additional benefit of the venture meter is its durability – it does not have the "sharp edge" profile of the orifice meter, therefore, it does not suffer from potential erosion issues and has a greater ability to accurately meter contaminated on non-homogeneous fluids.

The benefit of the venturi meter over the orifice meter lies in the reduced pressure loss experienced by the fluid.

Venturi meters can be used on connection sizes ranging from 0.25 to 4 inches and have accuracies in the range of 0.25 to 2.0 percent, depending on fluid type and installation. Venturi meters can cost from $1,000 to $5,000.

Differential Pressure – Annubar Meter. The annubar flow meter (a variation of the simple pitot tube) also takes advantage of the velocity-pressure relationship of flowing fluids. In this case, the device causing the change in pressure is a pipe inserted into the natural gas flow. Contained within this pipe are two smaller tubes with holes or ports evenly spaced along the length. Figure 5.21 presents the components of the annubar flow meter. When properly installed, one tube faces directly upstream and one downstream. These tubes and ports become the pressure detection points for the meter; the upstream-facing ports measure the flowing pressure (i.e., velocity pressure) and the downstream port measures the static pressure. Using these measured pressure values and the previously mentioned pressure-flow relationship, the flow rate is calculated.

Annubar Flow Meter Advantages/Challenges

Advantages:
- Limited resistance to flow
- Good accuracy and repeatability
- Lower installation cost – particularly on larger pipe diameters
- Expanded turndown ratio.

Challenges:
- Installation needs proper lengths of pipe for accurate measurements.

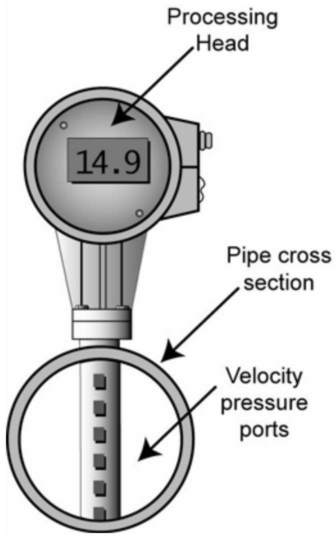


Figure 5.21. Typical Annubar Meter

Annubar flow meters have a turndown ratio of up to 10:1 and are relatively easy to install. These meters can make measurements on pipe sizes from 2 to 100 inches to an accuracy of 2 percent. Annubar meters can cost between $1,000 to $3,000, depending on size and accuracy.

5.6.2.3 Velocity Meters

Another means to determine fluid flow is by a technique that directly relates to the fluid's velocity. Velocity meters determine fluid flow by measuring a representation of the flow directly. Because the fluid's velocity is measured (i.e., not the square-root relationship to determine velocity as with differential pressure meters), velocity meters can have better accuracy and usually have better turndown ratios than other meter types.

Velocity – Turbine Meter. Turbine meters operate as their name implies. A multi-blade impellor-like device is located in, and horizontal to, the fluid stream. As the fluid passes through the turbine blades, the impellor rotates at a speed related to the fluid's velocity. Blade speed can be sensed by a number of techniques including magnetic pick-up, mechanical gears, and photocell. The pulses generated as a result of blade rotation are directly proportional to fluid velocity, and hence flow rate. Figure 5.22 details the components of a typical turbine meter. It should be noted that there are a variety of turbine designs and mounting configurations, of which Figure 5.22 highlights the concept.

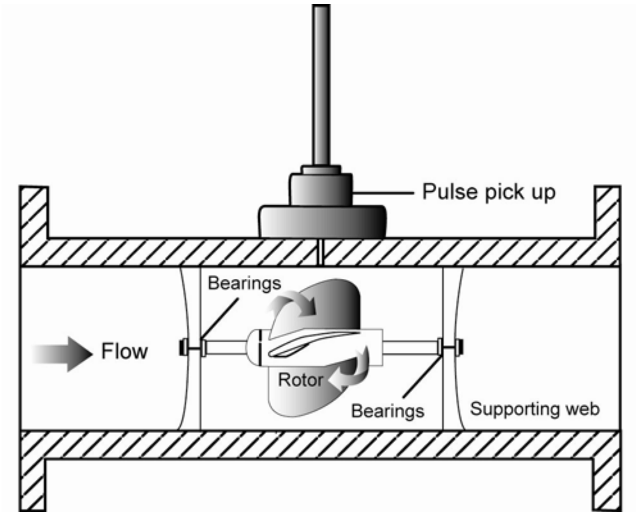


Figure 5.22. Typical Turbine Meter

Because turbine meters have mechanical elements in the fluid stream, they meters can be susceptible to wear and resulting inaccuracies. Of particular concern is the bearings that, if exposed to corrosive or contaminated fluids, can quickly wear and result in inaccuracy. The high-temperature/chilled water applications for turbine meters are typically for larger industrial metering functions. Turbine meters are used on connection sizes ranging from 2 to 20 inches and have accuracies in the range of 0.5 to 1.0 percent, depending on fluid type and installation. Turbine meters can cost from $500 to $5,000, depending on size.

Velocity meters can have better accuracy and usually have better turndown ratios than other meter types.

Velocity – Vortex Shedding Meter. A vortex shedding meter senses flow disturbances around a stationary body (called a bluff body) positioned in the middle of the fluid stream. As fluid flows around the bluff body, eddies or vorticies are created downstream, the frequencies of these vorticies are directly proportional to the fluid velocity. Figure 5.23 presents the typical vortex shedding meter.

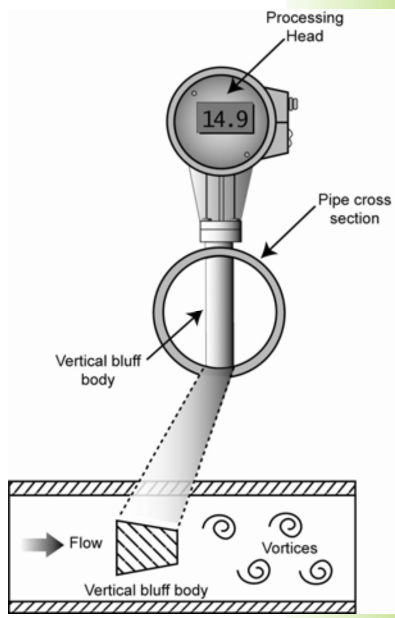


Figure 5.23. Typical Vortex Shedding Meter

As the vorticies are developed along the bluff body, they grow and are detached – it is this detachment that is electronically sensed and totalized. Because the vortex shedding meter has no moving parts, it is a very reliable method of water measurement. As with the other non-positive displacement meters, the vortex shedding meter is used in very specific high-temperature hot water/chilled water applications; good examples are for boiler feed water metering or for chilled water flow metering. Vortex shedding meters can be used on connection sizes of 1 to

One of the most attractive aspects of ultrasonic flow meters is that they are completely non-intrusive.

12 inches and has accuracies in the 1- to 2-percent range. Vortex shedding meters are relatively expensive, typically costing between $4,000 and $6,000.

Velocity – Ultrasonic Meters. Ultrasonic meters function through the basic relationship between the velocity of a fluid and its accompanying frequency shift – also know as the Doppler effect. One of the most attractive aspects of ultrasonic flow meters is that they are completely non-intrusive. That is, this technology does not require any permanent modifications or penetrations to piping or disruption of service for installation. All ultrasonic meters mount on the outside of the piping and can be used as both temporary and permanent metering.

There are two styles of ultrasonic flow meters available: Doppler meters and transit time meters. The Doppler meters function by measuring the frequency shift of the moving fluid to calculate flow. This technology works best when the fluid has suspended solids, bubbles, or other particles to reflect the ultrasonic signal. Figure 5.24 presents the function of the Doppler ultrasonic meter.

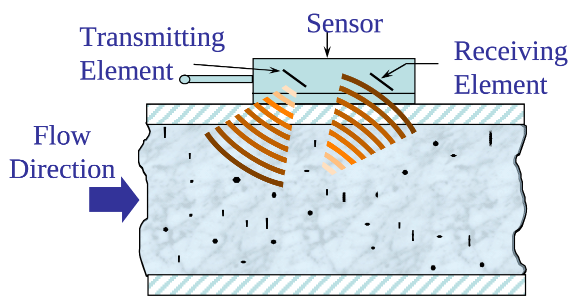


Figure 5.24. Doppler Ultrasonic Flow Meter

The transit time meter makes use of a transmitter and receiver mounted on opposite sides of the pipe. As fluid moves through the system, the first transducer sends a signal and the second receives it. The time it takes for the signal to arrive is proportionate to the flow rate. Different from the Doppler meter, the transit time meter needs clean and viscous liquids for best accuracy. Figure 5.25 presents the function of the transit time ultrasonic meter.

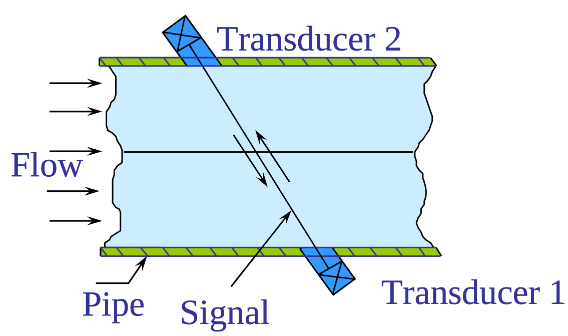


Figure 5.25. Transit Time Ultrasonic Flow Meter

Because ultrasonic meters have no moving parts, they are very reliable. These meters can be used on connection sizes up to 20 inches or larger, and have accuracies ranging from 1 to 5 percent. Both types of ultrasonic meters are relatively expensive, costing between $2,000 and $7,000.

5.6.3 Recording Intervals

Due to the way water is usually purchased and used, the data-recording interval is not as critical as it is for electricity. However, an ability to record water use at least hourly, if not every 15 minutes, can afford some diagnostic capabilities. One such capability would be to diagnose proper water flows and volumes based on known water uses. The best opportunity is to have the ability to modify the interval (at times to a shorter more refined interval) for temporary diagnostics and then return the setting to the longer more manageable interval.

Due to the way water is usually purchased and used, the data-recording interval for water is not as critical as it is for electricity.

5.6.4 High-Temperature/Chilled Water Meter Maintenance

Depending on the meter technology, installation, and quality of water delivered, water meters generally require limited maintenance. Procedures followed should be those as recommended by the manufacturer. Pending their availability, below are some general maintenance guidelines presented by meter technology.

Positive Displacement Meter

Monthly Inspections

- All connections for water leakage
- Noisy operation internal to meter
- Consistent and smooth register operation
- General meter cleanliness

Annual Inspections

- Calibration according to manufacturer's recommendation or if trended data indicate miscalibration.

Differential Pressure Meter

Monthly Inspections

- All connections for water leakage
- Abnormally loud or discontinuous sounds internal to meter
- Check for properly connected and sealed pressure taps
- General meter cleanliness

Annual Inspections

- Check orifice diameter and edges for wear, roughness, or material buildup
- Check venturi for cleanliness and corrosion at throat. Clean and smooth all internal surfaces.
- Check for well connected and sealed pressure taps

- Calibration of differential pressure sensors/transmitters according to manufacturer's recommendation or if trended data indicate miscalibration.

Velocity Meter

Monthly Inspections

- All connections for water leakage
- Abnormally loud or discontinuous sounds internal to meter
- General meter cleanliness

Annual Inspections

- Impeller blades should be checked for wear or damage
- Impeller bearings should be checked for wear
- Calibration of velocity meter according to manufacturer's recommendation or if trended data indicate miscalibration.

Ultrasonic Meter

Monthly Inspections

- Transducer positions and attachment to piping
- Cleanliness of transducer/piping interface
- Verification of piping isolation (i.e., no vibration in metering section)
- General meter cleanliness

Annual Inspections

- Calibration of meter according to manufacturer's recommendation or if trended data indicate miscalibration.

While other outputs options are available, calibrated pulses are the most common and relatively easy to work with.

5.6.5 High-Temperature/Chilled Water Metering Data Output/Communications Considerations

While other outputs options are available (e.g., 4 to 20 milliamp, 0 to 5 volt, Modbus), calibrated pulses are the most common and relatively easy to work with. Chapter 6 addresses in more detail the different output and communications options.

When specifying the water flow meter, the pulse calibration is a critical parameter. Important in this specification is an understanding of the range of expected flow and necessary resolution of output. There are situations where too high of a pulse count (i.e., too high of a frequency) can result in saturation of the data logger or other collection device. A saturation condition usually results in loss of data and erroneous pulse counts; therefore, it needs to be avoided. Meter and data logger vendors should be consulted when determining the appropriate pulse count and calibration.

5.6.6 High-Temperature/Chilled Water Meter Selection Considerations

- Determine the temperature ranges the meter will operate in.
- Determine expected range of water flows and pipe sizes.
- Determine the accuracy requirements over the flow range.
- Identify any physical installation requirements for meter location, straight lengths of piping, available communications, etc.
- Communication interoperatability – consider standardization on communication between meters and other data acquisition systems.
- Specification considerations – at the outset, consider a formal specification development so future additions ensure future compatibility.
- Data processing – how will the collected data be processed? Does the metering equipment vendor offer this function/service? Do not overlook the effort it will take to create a process to collect, store, and archive the data.
- Facility staff buy-in – make certain those staff that will be installing, maintaining, and most importantly, using the data have a voice in meter selection.

Standardization on communication between meters and other data acquisition systems needs to be considered.

5.6.7 High-Temperature Hot Water/Chilled Water Meter Selection Criteria

Table 5.4 presents some of the more common water metering technologies and key criteria for selection decisions (Sullivan et al. 2004; Carbon Trust 2005).

Table 5.4. Common Water Metering Technologies and Key Criteria

Criteria	Positive Displace-ment	Orifice	Venturi	Turbine	Vortex Shedding	Ultrasonic Dop/TT
Accuracy	Good	Moderate	Good	Good	Good	Moderate
Turndown Ratio	10:1	<5:1	< 5:1	10:1	20:1	10:1 / 20:1
Repeatability	Good	Good	Good	Low	Very good	Good
Installation Ease	Easy	Easy	Moderate	Challenging	Moderate	Very easy
Pressure Loss	Medium	Moderate	Low	Moderate	Low	None
Recalibration Needs	Infrequent	Frequent	Infrequent	Frequent	Infrequent	Moderate
Capital Cost	Low	Low	Moderate	Moderate	Moderate	High
Installed Cost	Moderate	Low	Moderate	Moderate	Moderate	Low
Maintenance Cost	Low	High	Moderate	Moderate	Low	Low

5.6.8 References

Carbon Trust. 2005. *Good Practices Guide: Reducing Energy Consumption Costs by Steam Metering*. Available at: http://www.carbontrust.co.uk/Publications/

FEMP. 2007. *FEMP Metering Training Course Session 2: Metering Technologies, Communications, and Data Storage*. April 4, 2005. Available at: http://eere.pnl.gov/femp/metering_webcast.stm

Sullivan GP, R Pugh, AP Melendez, and WD Hunt. 2004. *O&M Best Practices: A Guide to Achieving Operational Efficiency, Release 2.0*. PNNL-14788, prepared by Pacific Northwest National Laboratory for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/operations_maintenance/om_bpguide.html

When specifying the water flow meter, the pulse calibration is a critical parameter.

Chapter 6 Metering Communications and Data Storage

An integral part of the overall metering system is the mode of communications from the sensors to the meter and then from the meter to the point of data storage, analysis, and archiving. The communication from sensor to meter is usually handled internal to the meter and largely transparent to the user. The communication from the meter to the ultimate storage, analysis, and archiving is the focus of this section.

Regardless of the meter type, once data are collected they need a communication pathway to a location where the data will be processed, stored, and used. This pathway should be amenable to the various meter output types – some of the more common output types include:

- Analog output – typically, 4 to 20 mA or 0 to 5 volts dc
- Contact closure – pulse type output
- Digital output – digital pulse
- Digital signal – outputs using networked communications (e.g., Ethernet, Modbus, HART).

Modern meter systems benefit from recent developments in communications technologies.

Many of the newer digital-signal output meters can output multiple signal types offering a variety of communications options. These meters can be serially addressed, affording a lowered installed cost through reduced wiring installation and expense (i.e., multiple meters communicating on one pair of wires back to the data-collection terminal). Often these outputs can be viewed on local displays integral to the meter. These displays are quite useful for field set-up, calibration, verification of function, and troubleshooting.

6.1 Traditional Communications Options – Non-Automated

Modern meter systems benefit from recent developments in communications technologies. Over the past 20 years, communications have moved from requiring a hand-written recording of the metered value to a manually entered electronic recording to a locally transmitted electronic value. These data collection/communications modes are still in practice and are described below.

- ***Sneaker-net Data Collection***. A largely outdated, yet still practiced, method of manual meter reading involving writing down or keying in to a hand recorder the metered data. This data collection practice is inefficient, inaccurate, and discouraged in most applications.

- ***Mobile-Radio Data Collection***. This technology makes use of close-proximity radio frequency (RF) communications where by data are transmitted by the meter to a receiver – usually located in a slowly moving vehicle. While more accurate than sneaker-net, it still has an in-field manual collection component – driver and vehicle.

With the enactment of EPAct 2005, which explicitly states that metered data will be collected automatically, via automated meter reading (AMR) and made available at least daily, federal agencies are now required to use AMR – where practicable. As such, the following section presents the AMR systems that are more common and applicable to the federal sector.

6.2 Modern Metering Communications: Automated Meter Reading (AMR)

AMR systems, both wired and wireless, are increasingly being used owing to their availability, reliability, and decreasing cost. Many utilities, large corporate campuses, and universities are finding AMR not only to be convenient, but to make good business sense. When developing the communications portion of your metering program, it is important to consider what existing communications infrastructure you can take advantage of (e.g., building automation system, local area network) to potentially lower the cost of AMR. In addition, if you have a large site with distributed buildings you may find benefit in considering multiple communications technologies (e.g., networks in one area, phone lines in another, and wireless in a third) to gain the necessary communications coverage.

Below are the predominant AMR technologies along with some of the benefits and challenges of each.

Phone Modem. Taking advantage of telephone modem technology in both hardwire and wireless (i.e., cellular), this communications solution is the oldest and traditionally most reliable of the technologies. In typical applications, automated software (usually from the metering equipment vendor) is used to dial (phone-in) the modem daily to retrieve accumulated data. In addition to the phone-in systems, there are meters that can phone-out at preset times or at specified data accumulation levels. It should be noted that phone lines do not have to be dedicated to the meter(s) they serve; there is no reason meters cannot share a phone line with other applications – even personal office phones. Shared phone line applications can use off-hours for data communications and, therefore, do not interfere with other business-related uses.

Phone Modem

Advantages:
- Proven technology
- A secure and private network
- Usually available

Challenges:
- Can be expensive
- No access to real-time data
- Wired installation (hardwire solution) using additional equipment (modem)

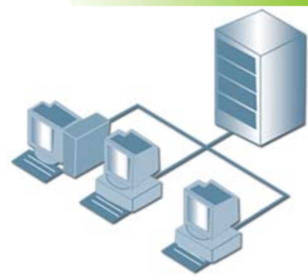
Local Area Network. Using an existing building or site's computer network to serve as the communications path for the metering system can be very economic. When properly configured, meters can communicate over this network using a variety of open protocols, including Modbus, HART, TCP/IP, BACnet, etc. In addition, these meters usually can be serially addressed and linked together (daisy-chained) to minimize wiring installation and expense.

Beyond the local area network (LAN), wide-area networks (WANs) can be developed by linking more than one of these networks together (usually via phone lines or through wireless solutions). This becomes useful to large sites with many distributed buildings and locations. Additional benefits to the LAN solution include the ability to share data throughout the network and view data in real time. Prevalent concerns with using a LAN for data communications stem from perceived security issues with transferring data over secure networks and potential access to the LAN via the metering points. In both cases, these concerns can be addressed with typical LAN security protocols. As is often the case, some level of education on the system, its operation, and security may be necessary – a small demonstration of the system may help convince skeptical IT or information-security staff.

Building Automation System. By using an existing Building Automation System (BAS), we again take advantage of a site's previous investment in existing infrastructure. In this case, the wiring used for BAS communication becomes the metering communications path. In this case, the meters are treated as other "points" on the BAS and function much as other sensors or points on the system (i.e., communicate to and from the central host computer). The BAS is a workable solution only when there is excess capacity to add points and system software is capable of using the meter's data output protocol – both of these factors need be verified with the BAS and metering equipment vendors. An additional constraint to the BAS solution relates to the host computer's ability to allocate memory for these data and offer an ability to retrieve data sets in an automated fashion.

Radio Frequency/Wireless Networks. Becoming increasingly available and economic, wireless radio frequency (RF) communications makes use of wireless transmitters and receivers to communicate metered data. Wireless communication (FEMP 2007) offers the benefits of lowered installation cost, flexibility in metering locations, and minimizes disruption in service when compared to other options. Some of the limitations to wireless communications include the effective distance of communication (typically less than 300 feet) and the building's materials

Local Area Network



Advantages:
- Proven technology
- Increasing availability
- Always connected
- Data sharing opportunities

Challenges:
- Network/IT security concerns
- Wired installation – need for network connectivity

Building Automation System

Advantages:
- Usually available
- Fast communications
- Always connected

Challenges:
- Potential system compatibility issues
- Potential data availability issues

of construction that may impede or block the RF signal. Both situations can be mitigated by using a repeater or mesh network configuration. Similar to the LAN solution, wireless communications has perceived challenges including security issues and potential for interference with other sensitive communications equipment. In many cases these concerns are unfounded, yet some level of education on the system, its operation, and security may be necessary – a small demonstration of the system may help convince skeptical IT or information-security staff.

Power Line Carrier. This technology uses existing electrical wiring, both internal and external to buildings, as the communications conduit. While making use of the existing infrastructure gives this technology and economic advantage, some of the limitations relate to speed and quantity of data transfer and the ability to transfer data across standard electrical transformers. Organizations making productive use of this technology, notably utilities and sites with many distributed buildings, do so by spreading the considerable installed cost over many metering points.

6.3 Data Storage Software

Assuming proper data collection and communication, some form of data storage system will be needed. Data storage needs will depend on the number of meters connected, the number of parameters metered, the data interval, and the expected need for access to historic data. In most cases, one of any number of commercially available database software systems will function well for data storage and software interface.

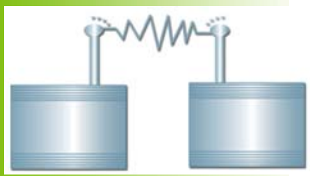
The specific requirements of the data storage/database system should be decided with assistance from site IT staff or others knowledgeable, or those who will be using the system. Below are draft specifications based on work done for the California Energy Commission Public Interest Energy Research Program (PIER) and the Building Technologies Program of the U.S. Department of Energy (CEC 2007).

6.3.1 Data Storage Specification Considerations

- Data shall be stored in a structured query language (SQL) compliant database format or time series format. Minimum requirements are a SQL server or equivalent.

- The database shall allow other application programs to read and access the data with appropriate password protection while the database is running. The database shall not require shutting down in order to access or have data added.

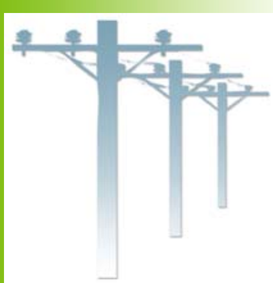
Wireless



Advantages:
- No communication wiring to install
- Fast communications
- Always connected

Challenges:
- System cost – though prices are coming down
- Perceived RF interference issues
- Distance and materials limitations
- New system, new infrastructure

Power Line Carrier



Advantages:
- Uses existing infrastructure
- Always connected

Challenges:
- Speed of data transfer
- Technical issues with transferring data past transfers

- Trend data shall be archived in a database from field equipment in time intervals no less than once per day.

- Storage on the field equipment will be reset once data are exported to allow for trending if communication is disrupted. Data will be uploaded once communication is re-established.

- Blank or null values in the database will be replaced with actual data. Calculations and other metrics will be updated once controller data is uploaded. This overall system update to check for new data should be automated to run once a day.

- All data shall be stored in database file format for direct use by third-party application programs (e.g., an Energy Information System [EIS] as discussed in Chapter 7).

- Sufficient data storage capacity will be able to store at least two years of data for all data points. In addition, storage capacity will also allow for compression of one year of data for historic trends and archiving.

- Time stamps shall be collected on all data. The time stamp, depending on system architecture, will be captured at the field controller or system controller and directed to the database archive.

- Exported data shall contain no duplicate records or duplicate time stamps in output files. Each date/time stamp for a specific point shall be unique. The export query shall be for a specific point or multiple points in a defined group.

- Date/Time fields shall be in a single column in a format automatically recognized by common spreadsheet, database software tools, or EIS.

- The data shall be fully contained in a single file or table for each point. Data shall not span multiple files or database tables. Users can have the option to modify export file start and end file date span depending on third-party program requirements to evaluate the data.

Key to productive use of data is the access for analysis, whether done in-house or as part of a third-party EIS package or agreement – see Chapter 7 for more details.

Sufficient data storage capacity will be able to store at least two years of data for all data points.

6.4 Data Storage Hardware

The computer hardware for data storage and software execution should have ample processing power and memory to run the chosen database system and to process, store, and archive all collected data. Fortunately, such activities can be handled quite easily with modern stand-alone personal computers and/or

The computer hardware for data storage and software execution should have ample processing power and memory to run the chosen database system and to process, store, and archive all collected data.

workstations. One key recommendation is that whatever system is chosen, it be dedicated to this activity. It is also recommended that this system have an automated back-up function (typically daily) to a separate system/server for data protection and archiving.

An increasingly popular option for data storage involves an agreement with a third-party organization (e.g., an EIS vendor or other data-hosting entity) whereby all data are collected, stored, and backed-up on vendor computer servers. In this case, the client is given access, usually over the web, to all data and analyses for addition processing, reporting, and downloading.

6.5 References

California Energy Commission (CEC). 2007. *Continuous Performance Monitoring Systems, Specification Guide for Performance Monitoring Systems*. Available at: http://cbs.lbl.gov/performance-monitoring/specifications

Energy Policy Act of 2005 (EPAct). 2005. Public Law 109-58, as amended, Section 103, Energy Use Measurement and Accountability, Section 543 (42 USC 8253), (e) Metering of Energy Use.

FEMP. 2007. *Wireless Temperature Sensors for Improved HVAC Control*. DOE/EE-0319, U.S. Department of Energy, Energy Efficiency and Renewable Energy, Federal Energy Management Program, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/pdfs/tir_wirelesstempsensors.pdf

Chapter 7 Data Analysis and Use

7.1 Introduction

Depending on the interval and collection frequency, metered data can accumulate quickly and become overwhelming unless some level of automated data processing is implemented. At the outset of any metering activity, it should be made clear that meters provide data and these data generally do not constitute information or knowledge. The reality of data analysis comes in the recognition that data needs to be processed to create information (knowledge) before any proactive actions can be taken. To be successful in their metering activities, the federal sector must recognize that meters and data alone are not the answer; success comes when the data are processed to create information and this information used for action.

This chapter focuses on suggestions for productive uses for metered utility data as well as discusses some of the options for data analysis and processing.

At the outset of any metering activity, it should be made clear that meters provide data and these data generally do not constitute information or knowledge.

7.1.1 Data Analysis and Energy Information Systems

An Energy Information System (EIS) is an integrated development combining analytical software and hardware (sensors and meters) with a communications system to collect, analyze, and report building energy/resource data. While these systems can be installed in a "turnkey" sense (i.e., all sensors, meters, and software are installed), many applications make use of existing hardware and communications and the EIS becomes strictly a software solution. The balance of this section will focus on the software data analysis aspects of the EIS solution.

The software aspect of the EIS can take the form of a very simple (in-house developed) spreadsheet-based routine for processing metered data, to a very complex (third-party purchased/licensed) software package with many sophisticated routines and statistical analysis capabilities.

As with the different offerings, there are a variety of fee arrangements available through these vendors. Some EIS organizations offer their service under a licensing agreement allowing only a certain number of users or "seats." Other EIS organizations offer unlimited users under a time-based subscription service and still others offer their product as a one-time software purchase with fee-based technical support. A list of EIS vendors can be found in the following references: CEC (2007) and LBNL (2002).

EIS Development/Selection Considerations. Prior to making the decision to develop an in-house EIS versus purchasing/licensing a third-party product (or

Before selecting an Energy Information System vendor, you may consider developing some vendor-selection criteria specific to your site.

something in between), your organization needs to determine the options and expectations of the EIS in at least the following areas (CIPEC 2004):

- Definition of facility objectives – need to be clear on how the EIS will be used, how it will improve resource efficiency, and its contribution to the financial payback of the overall metering system.
- EIS integration with other IT systems – an important consideration prior to EIS selection/development is what existing infrastructure can be used. Prior to the EIS decision, a survey of existing facility software, hardware, communications, meters, and capabilities is recommended.
- Identify key reporting outputs – how will the outputs of this system be used to fulfill the objectives of the facility and its management? How will the outputs be made available (paper copy, email reporting, web-based reporting) and what sort of summary options are available?
- Data-collection needs – what are the data-collection requirements necessary to achieve the key reporting outputs? Are these available with existing metering elements?
- Data analytics – what analysis, statistical and/or regression routines are needed to transform the data to into the information desired? Are the chosen analytics capable of handling the size, frequency, and complexity of anticipated data?
- Management support – has a budget been developed addressing expenses such as ongoing training, periodic testing, technical assistance, and troubleshooting?

EIS Vendor Selection Criteria. If you decide to use a vendor-based EIS system before selecting an EIS vendor, you may consider developing some vendor-selection criteria specific to your site. Below are some criteria developed as part of an EIS demonstration in California (LBNL 2006). While the criteria listed below may not align with your specific needs, it is highly recommended that you develop specific criteria well before you engage with EIS vendors. The following list presents the questions to consider when evaluating each vendor during the selection process.

Vendor profile:

- Does the vendor have experience and a stable business history in the particular EIS-related services?
- Does the vendor have experience working with industrial customers?

- Is the vendor capable of single source responsibility?
- Does the vendor have a regional office close by or in your state?

Metering:

- What type of data is the EIS designed to monitor/archive? Although most of the EIS products can be customized to archive any kind of data, some EISs may focus their functionalities on specific data types such as whole-building electricity, gas, or other utilities. If you are planning to perform more detailed diagnoses, built-in analysis functions for electric sub-meter, pressure, or temperature data will be helpful. Calculated data points and the capability to create a virtual data point from real measurement point values are also helpful.
- What is the system response speed? In general, communication response speed for industrial grade system is 200 to 500 milliseconds or less, and commercial grade is 1 to 2 seconds. For only monitoring purposes, a slower response speed is acceptable, while industrial control requires faster response speed than commercial.

Communications:

- Does the vendor have capability for two-way communication flow – monitoring and control?
- What types of data input are supported by the EIS? Types include pulse, 0 to 10 volt dc, 4 to 20 milliamp, digital, etc.
- What types of metering/communication protocol are supported by the EIS? Types include TCP/IP, BACnet, LonTalk, Modbus, Profibus, etc.
- If your facility uses some specific protocol or has some native equipment for the specific protocol, compatibility between the system and the EIS will enhance their performance.

Data Storage:

- What is the database compatibility for the EIS? Is it compatible with the following systems:
  - Web-service client with Extensible Markup Language (XML)
  - Open Database Connectivity (ODBC) compliant to interface third-party software application
  - Structured Query Language (SQL)
  - Application Program Interface (API) to communicate with specific field devises such as handheld equipment
  - Is the database and the data transfer through the Internet encrypted?

Some Energy Information Systems may focus their functionalities on specific data types such as whole-building electricity, gas, or other utilities.

Consider which analyses will be most useful and incorporate those into the Energy Information System as an automated function.

Data Output Considerations. The final element for consideration in EIS development or selection is the output information. Prior to development or selection, facilities staff need to review the objectives and goals of this entire metering system. Once identified, these can be used to help shape the type and form of EIS output necessary to achieve these objectives. Assembled below are a variety EIS output options collected from different vendors and resources. These are grouped into the categories of graphical outputs, analytical outputs, system-specific outputs, and utility outputs. While these categories are not all-inclusive, they should provide some guidance in identifying the capabilities and outputs advantageous to you and your systems. One additional caution, as you make your decisions on vendors and levels of service/outputs, keep in mind the associated volume of data and the necessary time to process and act on the data. The recommendation is to start with a manageable set of outputs that can be useful in the expected time allocated. Then, as the system becomes more integrated, look to add features and other options. To start – keep it simple.

Graphical Outputs: Consider these as the plots you and your staff interact with on a daily, weekly, and monthly basis. Make certain axes are scaled and labeled for intuitive understanding now and into the future.

- Daily profile: Time-series daily load profiles are displayed with time, in intervals of an hour or less, along the horizontal axis and load along the vertical axis.
- Day overlay: Overlay plots display multiple daily profiles on a single 24-hour time-series graph.
- Multi-point overlay: Allows viewing of multiple time series data points on the same graph.
- 3-D surface chart: Three-dimensional surface charts often display the time of day, date, and variable for study.
- Calendar profile: View up to an entire month of consumption profiles on a single screen as one long time series.
- X-Y scatter plots: X-Y scatter plots are useful for visualizing correlations between two variables.

Analytical Outputs: Consider which analyses will be most useful and incorporate those into the EIS as an automated function. The goal is to minimize the amount of exporting and re-analyses needed.

- Basic statistical analysis: Perform statistical calculation, such as mean, median, standard deviation, correlation, and regression.

- Benchmarking: Benchmark against building energy standards or public database such as EnergyStar.

- Intra/inter-facility comparisons: Benchmark against the building's historical data or across multiple buildings in the enterprise.

- Aggregation: Aggregate data among multiple data points. Integrate different energy units using energy conversions (e.g., kWh, Therm, etc., into Btu).

- Data mining (data slice/drill-down): Sum-up/drill-down time series data by monthly, weekly, daily, hourly, or trended interval.

- Normalization: Normalize energy usage or demand by some factors such as building area, number of occupants, outside air temperature, and cooling or heating degree-days (CDD, HDD) to make a fair comparison between buildings.

- Hierarchical summary: Summarize usage and cost information by different levels. For example, starting from equipment energy cost, individual building energy cost, site energy cost, to regional energy cost.

Benchmark EIS data storage against building energy standards or public database such as EnergyStar.

System-Specific Outputs: Look for customized analyses beyond the "graphical and analytical" outputs mentioned above. This type of analysis often takes multiple data points and use more complicated algorithms.

- Power quality analysis: Monitor the voltage or current phases for conditions that could have adverse affect on electrical equipment.

- Steam charts: Calculate temperature, pressure, specific volume, and enthalpy for saturated steam and water.

- Forecasting: Forecast future trends by historical data and related parameters.

- Validation, editing, estimation: A process performed to ensure quantities (kWh, kW, kVar, etc.) retrieved from meters are correct. The process includes validation of data within acceptable error tolerances, editing or correcting erroneous data, and estimating missing data.

- Equipment fault detection and diagnostics: Diagnose equipment failure or degradation based on customized algorithm and parameters.

One of the most common applications of metered data is for accurate billing of site tenants based on actual use instead of estimates based on square footage or occupancy.

***Utility Outputs**:* Consider how these data can be useful in interactions with your utilities. Typically, there are tools allowing rate comparisons, bill verification, etc.

- Invoice verification (bill validation): Utility bills are compared to meter readings (so called "shadow" metering) to validate accuracy of bills.
- Energy cost drilldown: Using energy tariff and usage data, calculate daily or hourly energy cost breakdown, instead of the usual cost that can only be seen in monthly utility bills.
- Real-time cost tracking: Calculates electricity costs every day or hour using real-time meter reading and rate tariffs.
- End-use cost allocation: According to user-defined parameters and algorithms, estimates end-use energy consumption from whole building energy. Generally used for cost allocation to building tenants. A common parameter definition is energy use per square foot.

7.2 Uses For Data – Metering Applications

Given that some level of data analysis and processing is enacted, there are a variety of potential applications for these data. Note that while all of these applications may not be applicable to a given facility currently, future considerations should be part of the planning process – as such, some of the more common applications of metered data are presented below.

Reimbursable Billing. One of the most common applications of metered data is for accurate billing of site tenants based on actual use instead of estimates based on square footage or occupancy. Federal sites with tenants (or federal tenants on private sites) are well advised to consider installing utility metering (gas, electric, water, steam) to not only provide accurate accountability of utility usage, but also send the tenant the correct price signal as an encouragement to save energy and other resources.

Validation/Planning/Reporting. Utility meters offer the facility staff the ability to validate existing metering ("shadow" metering) while allowing verification of usage and proper billing. While this activity may appear to have a minimal potential for savings, numerous cases of utility company errors are reported every year – and many of these result in large dollar value corrections, many in favor of the customer. Beyond validation, utility metering allows site staff to accurately comply with federal reporting requirements and offer better information for systems and site planning activities.

Utilities Interaction. In many parts of the country, electric utilities are offering a variety of creative rate-based products targeting a higher reliability of the electrical grid. Participation in most of these programs usually requires some level of advanced metering; sometimes this is provided by the utility, other times it is the requirement of the site. In either case, having access to advanced-metering data (usually 15-minute interval demand data) will allow a site to best understand their particular load characteristics when negotiating with prospective electric utilities and their offerings. A few of the more common utility offerings are described below:

- ***Time-of-use pricing***. These programs are designed to incentivize the "off-peak" use of electricity by offering reduced kW/kWh charges during pre-defined and fixed off-peak time periods. Electric meters with interval capability (at least hourly intervals) allow the user to understand the value of these programs to their specific electricity use characteristics. In addition, the data from these meters allow for scenario planning activities whereby the value of shifting loads to off-peak periods can be estimated.

- ***Real-time pricing***. Similar to time-of-use pricing, real-time pricing encourages decreased energy use during peak utility periods. However, rather than having predetermined fixed periods and associated energy costs, real-time pricing allows the utility to vary both-and does so giving the customer a nominal notification period. Sometimes these notifications are "day-ahead" or as short as "hour-ahead" notification. To take advantage of these offerings, facility managers need to have real-time metering and the flexibility to curtail loads commensurate with the utility needs and curtailment periods.

- ***Load Aggregation***. Agencies may want to combine facilities that are geographically separate from each other for purposes of acquiring and billing utility services. Such aggregation, depending on the base load and peak load characteristics, can result in lower utility rates rather than a separate utility account and the associated "fixed" charges for each site.

Energy Policy Act of 2005, Section 1252 "Smart Metering"

Section 1252 of EPAct 2005 requires that within 18 months of its enactment that states investigate and decide whether to mandate utilities to offer each customer a time-based rate schedule under which the rate charged by the electric utility varies during different time periods and reflects the variance, if any, in the utility's costs of generating and purchasing electricity at the wholesale level. The time-based rate schedule would enable the electric consumer to manage energy use and cost through advanced metering and communications technologies. If the states mandate time-based rate schedules, each electric utility would provide each customer requesting a time-based rate with a time-based meter capable of enabling the utility and customer to offer and receive such a rate, respectively.

Efficiency Opportunity Identification. Metering provides the data to begin validating equipment performance and efficiency. As previously described in Chapter 4, the metering hierarchy of starting with whole-building metered data (preferably 15-minute interval data) and looking for anomalies or unexplained events/usage is recommended. Once identified, these events become candidates for further analysis and trending, or as points for a more detailed level of metering using portable data loggers/meters at the panel, circuit, or end-use level.

Operational-Opportunity Identification. The focus here is on building "tuning." This activity uses the metered data to validate that existing systems are operational and being controlled as expected/recommended. Significant savings have been documented (Gregerson 1997; Haasl 1999; PECI 1997; Texas A&M 2002) in this area by identifying a variety of inefficiencies including inoperable night-time set-back features, by-passed variable frequency control devices, and defeated energy-efficiency measures such as HVAC economizers and boiler/chiller controls.

Power Quality Applications. Advanced meters can capture electrical anomalies such as transients, voltage disturbances, power factor, and harmonics in order to troubleshoot power quality problems. This can be especially useful when monitoring sensitive loads. Transients can cause premature failure of power-sensitive electronics in computers and other electronic equipment. Abnormally low power factor (usually a result of multiple and/or large inductive electric loads) can result in surcharges from utility companies. Using advanced meters will allow detection and documentation of power quality problems so solutions to those problems may be developed and implemented prior to equipment failure or high energy bills.

Measurement and Verification of ESPC Savings. In the federal setting, energy savings performance contracts (ESPCs) often involve the installation of efficiency measures in a small number of buildings on a large campus-type facility that contains a single revenue meter. The savings generated by the ESPC can be a small fraction of the facility's total energy use, and can be difficult to estimate these savings from analysis of monthly utility bills. For this reason, indirect methods such as modeling and engineering calculation are often used to estimate savings. If the buildings are individually metered, readings before and after the project can be used to establish both the energy-use baseline and the energy savings to a much higher degree of confidence. In many cases, there is a need to move from whole-building to end-use (i.e., metering at the equipment) to capture accurate savings estimates.

Emergency Response. During an electrical power emergency (such as experienced in California in 2000 and 2001), or during other utility shortages (such as the water drought in 2002), the manager of a federal facility may need real-time information in order to make decisions regarding physical plant closure or interruption of non-critical loads. A manager may want real-time feedback and, that the directions to staff to reduce utility use are being followed and are achieving the required result.

Benchmarking. Utility benchmarking is a process of collecting and trending building-level utility data for the purpose of comparison to the building's historic data or

Benchmarking Resources

Energy Star Portfolio Manager available at
www.energystar.gov/benchmark

Cal-Arch Benchmarking Tool available at
http://poet.lbl.gov/cal-arch/

Lawrence Berkeley National Laboratory Cleanroom Benchmarking:
http://ateam.lbl.gov/cleanroom/benchmarking/

Oak Ridge National Laboratory Benchmarking Spreadsheets for Office Buildings:
http://eber.ed.ornl.gov/commercialproducts/cbenchmk.htm

to a comparative building's data. Often, building benchmarking is accomplished using some normalization metric; for example: energy use per unit area (kWh/square foot/year) or water use per occupant (gallons/occupant/year). The value of benchmarking lies in the ability to develop comparisons usually relevant to some accepted baseline condition. Once generated, these comparisons become the basis for further investigation for operational improvements.

7.3 Working with Data – Examples from the Field

Interval data offer many benefits in identifying efficiency and operational opportunities. However, the data – even after processing – require active viewing to search for variability and trends.

Below is a collection of whole-building and end-use data for which some sort of variance was noted. These are presented to highlight the practical uses of interval data, what these data look like, and how evident some of the anomalies can be – once you start looking.

7.3.1 Interval Data for Efficiency Opportunity Identification

The value of benchmarking lies in the ability to develop comparisons usually relevant to some accepted baseline condition.

Objective: Use interval data to identify project opportunities.

Situation: Small administrative building at federal site. Standard hours of operation, typical occupancy density, whole-building interval electric meter installed.

Findings: Viewing the daily demand profile, notice relative "flatness" of profile from day to night. Flat demand profiles are indicative of buildings with 24-hour occupancy, or a disabled nighttime setback control feature. In this case, the control had been disabled to accommodate a series of night meetings held in the building and never reset. Figures 7.1 and 7.2 below present the data as found and corrected.

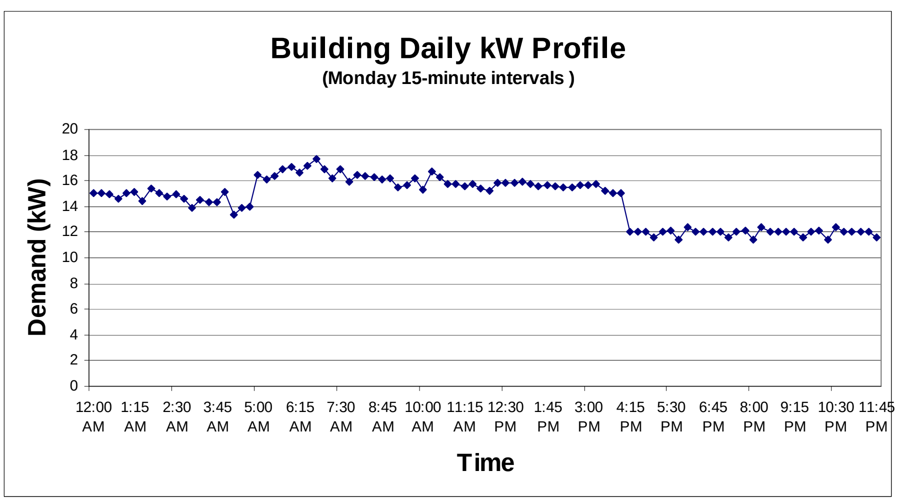


Figure 7.1. Daily Demand Profile – Nighttime Temperature Setback Disabled

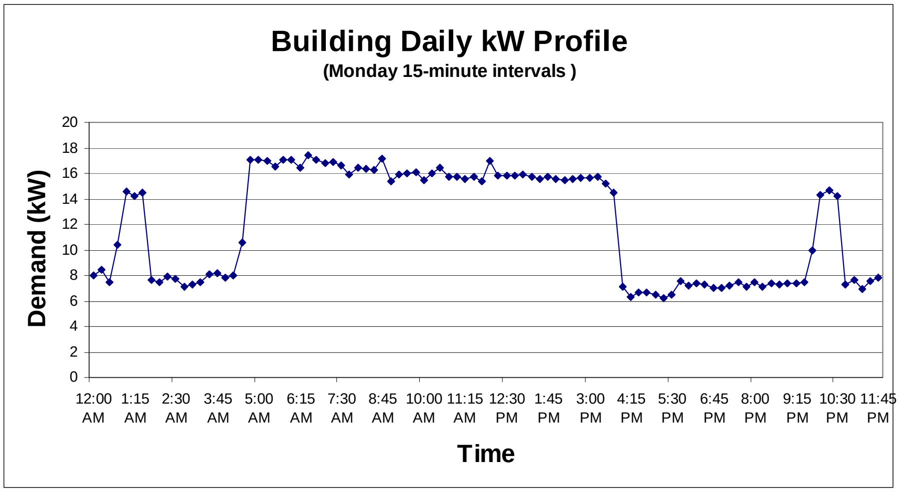


Figure 7.2. Daily Demand Profile – Nighttime Setback Enabled

Outcome: Once nighttime setback control feature enabled, significant decrease in nighttime electrical load – predominantly fan loads. Notice relatively high base load – may be candidate for lighting control retrofit or plug load analysis.

Interval data offer many benefits in identifying efficiency and operational opportunities.

7.3.2 Building Benchmarking

Objective: Use benchmarking to compare building energy performance – kWh/ft^2/month.

Situation: Two small, co-located training facilities with similar occupancy and hours of operation. Whole-building interval electric meter installed.

Findings: Viewing the monthly benchmark data (see Figure 7.3) shows Building A using roughly 20 percent more energy per square foot, each month. While there are a number of factors that could contribute to this, including

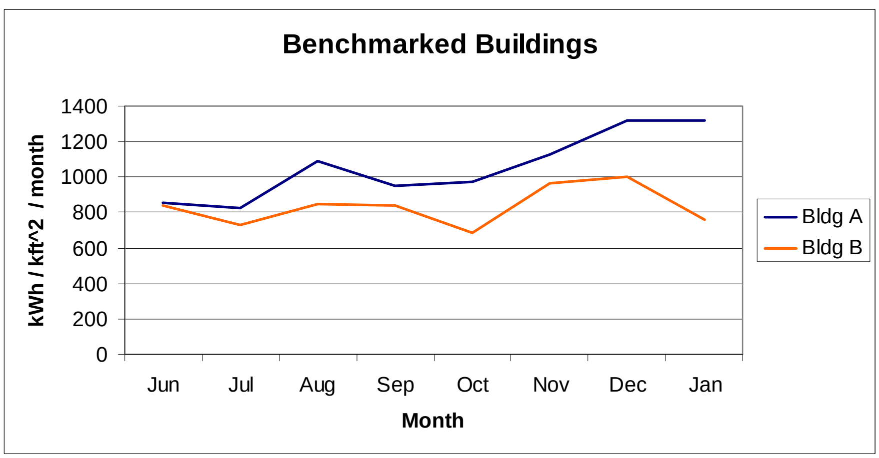


Figure 7.3. Building Benchmarking

occupancy variance, materials of construction, age/operation of equipment, and hours of operation – this type of variance is worthy of further exploration.

Outcome: Further exploration identified high nighttime lighting loads in Building A as part of the variance. Diverging load profile after December needs further exploration.

7.3.3 Operational Efficiency Identification

Objective: Use interval water-use data to identify water inefficiency.

Situation: Trending of water use in federal administrative building; whole-building interval water meter installed.

Findings: Viewing the daily interval water-use data highlights suspicious use pattern (see Figures 7.4 and 7.5), particularly during off-hours.

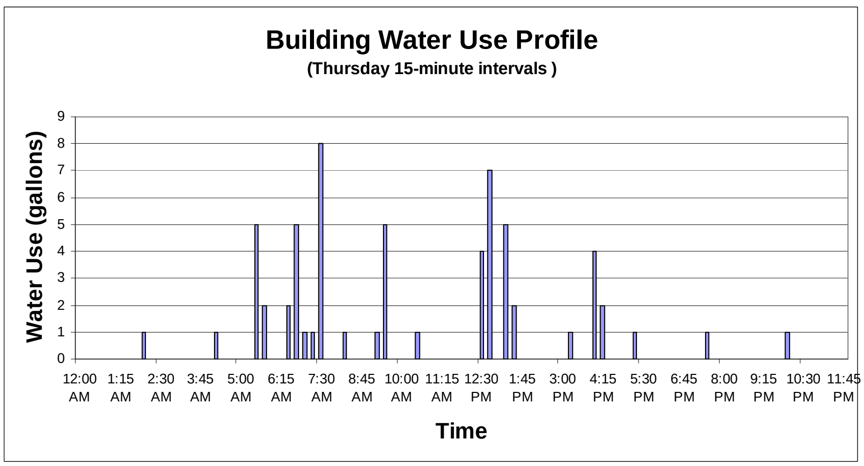


Figure 7.4. Building Water-Use Interval Data – Suspicious Pattern

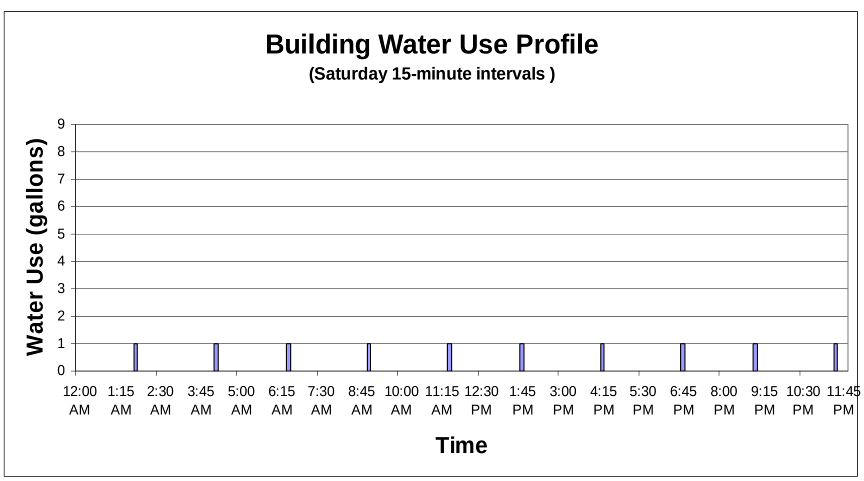


Figure 7.5. Building Water-Use Interval Data – Verification of Water Leak

Viewing the daily interval water-use data highlights suspicious use pattern, particularly during off-hours.

Outcome: Reviewing interval data for unoccupied period – see Figure 7.5 – Saturday highlights suspicion of water leak. Leak confirmed as leaking restroom fixtures in men's bathroom.

7.3.4 Peak Demand Identification/Reduction

Objective: Use interval demand data to identify, value, and ultimately reduce peak demand (LBNL 2004).

Situation: Federal facility with process loads and peaking demand. Whole-building interval electric meter installed.

Findings: By building a load duration curve – curve presenting the number of hours (or, as presented, percent of time) that a building's demand is greater than some predetermined value – opportunities for valuing and reducing peak demand become evident. In the graph and accompanying data below (Figure 7.6 and Table 7.1), it is evident that for only 1 percent of the time (or about 7.5 hours) during the month of July the demand was above 2,102 kW.

By building a load duration curve, opportunities for valuing and reducing peak demand become evident.

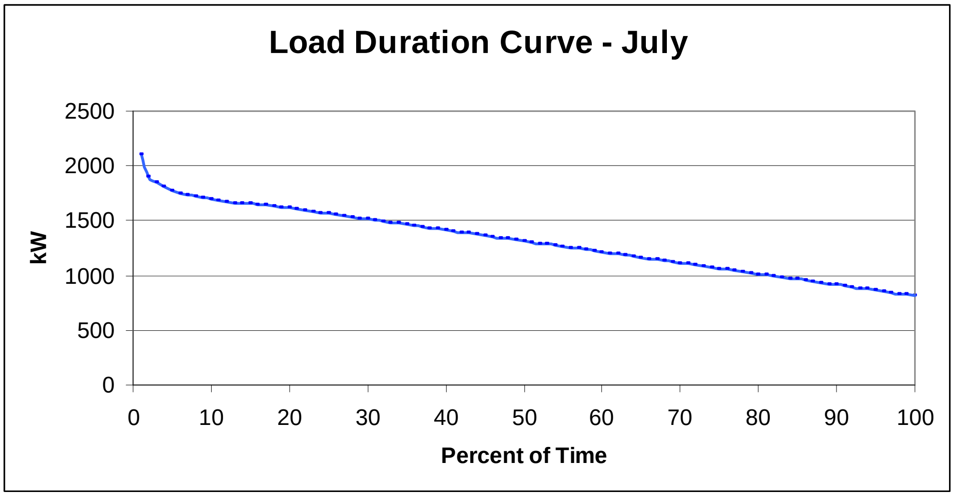


Figure 7.6. Load Duration Curve

Outcome: Given that peak demand for the month was 2,289 kW allows for calculation of the difference between the peak and the 1 percent value (2,289 – 2,102) = 187 kW. This difference, 187 kW, represents demand that occurred during just 7.5 hours in the month. At a peak demand charge of $17.92/kW, this demand cost over $3,350 for this month. Put differently, if this demand could have been avoided (during those 7.5 hours), the monthly savings of $3,350 could have resulted. This general concept is scalable (i.e., consider avoiding the top 2 percent) and, when spread over 12 months, can have a significant monetary impact. To affect these savings, a clear understanding of the site's utility rate structure (not always an easy endeavor) is necessary.

Table 7.1. Load Duration Curve Data

Percentage of Time (Month of July)	Electric Demand from Interval Data
Peak	2,289
1%	2,102
2%	1,905
3%	1,849
4%	1,807
5%	1,768

7.3.5 Operational Efficiency Opportunity Using Data Logger Data to Validate Boiler Operation

Objective: Use data logger (5-minute run-time, time-series data) to validate proper boiler operation.

Situation: Federal facility with boiler heating/process loads. End-use run-time data logger installed. Data reported are from peak-season loading conditions.

Findings: Reviewing the 5-minute run-time data (data collected with stand-alone magnetic field enabled logger placed near boiler combustion-air blower motor) reveals excessive cycling of boiler; Figure 7.7 presents these data. A bar in the figure rising from 0 to 1 indicates the boiler cycling "on," the bar returning from 1 to 0 indicates the boiler cycling "off." Therefore, each bar in the graph represents one on/off cycle.

Reviewing the 5-minute run-time data reveals excessive cycling of boiler; Figure 7.7 presents these data.

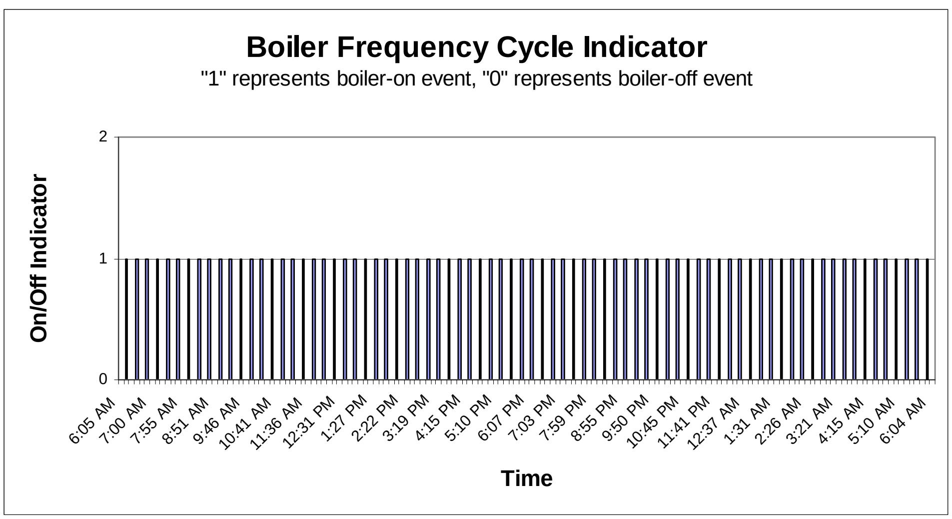


Figure 7.7. Boiler Cycling Frequency Data

Outcome: Processing these data reveals an average of 6.5 on/off cycles per hour – far in excess of the recommended 1-2, depending on load conditions. Further exploration uncovered gross boiler over-sizing due to partial decommissioning of building/process loads. The outcome recommendation includes installation of smaller, properly sized, and more efficient boiler to carry load.

7.3.6 Measurement and Verification of New Lighting Technology

Objective: Use electrical panel level (lighting circuit) demand (kW) data to verify manufacturer's claim of energy savings from new lighting technology (spectrally enhanced fluorescent lighting) installed at federal facility.

Situation: Measurement and verification of retrofit lighting installed at large administrative space on federal site. Panel-level interval metering installed.

Findings: Processing of the lighting panel data shows significant reduction in demand (kW) of the retrofit technology (spectrally enhanced fluorescent lighting) compared to the baseline technology (existing T-8 fluorescent lighting) with a clear presentation of savings. Figure 7.8 presents these data.

Processing of the lighting panel data shows significant reduction in demand (kW) of the retrofit technology.

Outcome: Savings validate manufacturer's claim of performance.

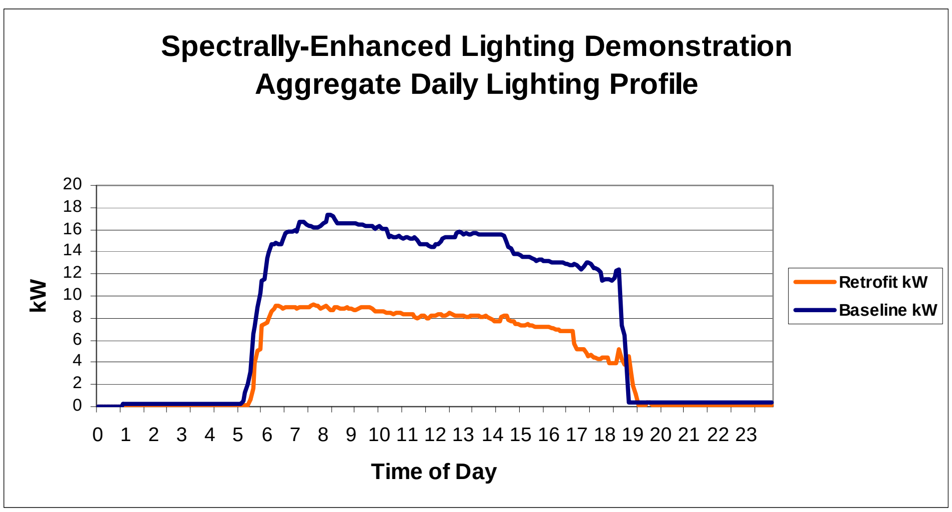


Figure 7.8. Measurement and Verification of Lighting Demonstration

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Chapter 8 Metering Economics

8.1 Introduction

We want to apply meters where it makes sense. This means meters should be applied when their application can be justified on the basis of cost-effectiveness – a measure relating the estimated costs to the estimated savings, such as a simple payback period.

Determining the cost-effectiveness requires us to estimate

- the cost to design, purchase, install, maintain, store data, and operate the meter/metering system, and analyze the data output, and
- the resulting energy cost savings.

This chapter examines these cost components and demonstrates how to evaluate the economic practicability of a metering application. This chapter also looks at the various financing options available to federal sites to purchase, install, and potentially operate their metering systems.

Meters should be applied when their application can be justified on the basis of cost-effectiveness.

8.2 Metering Costs (DOE 2006)

Metering system costs vary widely for a number of reasons: equipment specifications and capabilities, existing infrastructure, site-specific design conditions, local cost factors, etc. For this reason, this guide does not present specific cost estimates. Instead, we identify the main cost components that should be addressed when developing a metering cost estimate.

The metering cost estimate can be separated into three main categories: capital, labor, and recurring costs. More detailed descriptions of these categories and the types of costs to be included are provided below.

- **Capital**: Capital refers to the cost of the meters and all materials required to support their installation:
  - ***Meter purchase cost***. The purchase price depends on the features selected such as accuracy, memory, and mounting.
  - ***Ancillary devices***. Electric meters require current transformers (CTs) and safety switches. These devices may be built-in into a meter but are usually purchased separately.
  - ***Communications module***. There are a number of types of communication modules that can be purchased for electric meters: Handheld reader communicator, telephone modem, radio transceiver,

power line carrier modem, Ethernet modem, and SCADA interface RS232-RS485. Communications modules are usually ordered with the meter.

- ***Miscellaneous supplies***. Small compared to other hardware line-item costs, miscellaneous supplies include items such as wire, conduit, and junction boxes necessary to complete the installation.

- **Labor**: Labor covers the time charges for a crew and should account for planning and prep time, crew travel time, installation of all hardware required for a working installation, connection of the communications module, operational testing, and inspection. Examples of variables in the labor costs include the type of meter being installed (utility being metered and if the meter is intrusive or non-intrusive), service shut-downs that may need to be accomplished during off-hours, and trenching requirements for running cable.

- **Recurring costs**: Recurring costs are planned regular costs that support the ongoing operation of the meter/metering system.
  - ***Monthly communications fees***. These fees will vary based on the communications method selected.
  - ***Data collection and storage***.
  - ***Data analysis***: Data need to be analyzed on a regular basis (daily and/or weekly) with findings and recommendations issued.
  - ***Operation and maintenance***. Meters require periodic calibration and testing.

How Much Do Meters Really Cost?

Meter costs cover a range and are affected by a number of variables – type of metering, functionality of meters, communications and storage requirements, unique applications and/or installation requirements, etc. Coupled with the rapid evolution of metering products available in the marketplace, it is not practical to provide cost estimates in this guide; instead, system planners and designers are encouraged to contact metering equipment vendors, as well as network with other system planners and designers to tap into their experiences.

Of particular interest to the federal sector is the cost of advanced electric metering systems. Again, while these costs do vary based on the factors identified above, the tables below present a range of typical costs (Heller 2005).

Advanced Electric System Costs per Meter

Installation Cost	Low ($)	High ($)
Meter	1,000	1,500
Ancillary device	300	600
Communications (modem)	100	200
Software	0	100
Installation	500	1,000
Install phone line or LAN	0	2,000
Total	1,900	5,400

Metering System Ongoing Costs per Meter

Recurring Costs per Month	Low ($)	High ($)
Phone/LAN	5.00	40.00
Data collection	0	1.70
Data analysis/billing	4.50	4.50
Total	9.50	46.20

8.3 Metering Savings Potential

The lack of federal metering experience makes it difficult to estimate the energy cost savings that can be expected from a site-wide metering program. Estimates of energy savings have ranged from 1 to 20 percent. Table 8.1 presents metering-related savings ranges based on different uses for metered data.

Table 8.1. Metering Savings Ranges (DOE 2006)

Action	Observed Savings
Installation of meters	0 to 2% – the "Hawthorne effect"
Bill allocation only	2½ to 5% – improved occupant awareness
Building tune-up and load management	5 to 15% – improved awareness, identification of simple operations and maintenance improvements, and managing demand loads per electric rate schedules
Ongoing commissioning	15 to 45% – improved awareness, ongoing identification of simple operations and maintenance improvements, and continuing management attention

As Table 8.1 demonstrates, the savings realized by a metering program depend largely on the actions taken with the data.

The benefits of installed meters are minimal if the meters are simply installed across a site but there is not any follow-up action taken with the data. There may be some savings realized due to the Hawthorne effect, but even these savings will decline over time if the occupants realize that the data are not being used.

The realized savings will increase as the data are more widely applied. It is anticipated that many federal sites will implement a metered data cost allocation approach once their metering systems are in place. This, in turn, will lead to increased utility savings since the building occupants will then have a financial incentive to reduce or manage use.

The Hawthorne Effect (Clark 1999)
The Hawthorne effect refers to an often-cited finding from a study conducted in the 1920s and 1930s at the Hawthorne Plant of the Western Electric Company in Cicero, Illinois. The study intended to look into the impacts of physical and environmental influences on the workplace. This key finding was that individual behaviors may be altered – typically in the direction of the desired change – because workers know they are being studied.

Even greater savings can be realized when the data are used to support actions to optimize building operations. This includes

- Verifying or fine-tuning building and/or equipment startup and shutdown times.
- Actively managing electric demand to minimize the impacts of time-based demand charges.

Only in extreme cases should savings greater than 15 percent be considered for estimating benefits. Such a case would be a building or buildings that have a lot of efficiency opportunities due to very poor operations or neglect.

8.4 Cost Justification Methodology

EPAct requires that federal buildings be metered for electricity "where practicable." The following formula to cost-justify an electric meter (or other utility meters) was presented in DOE (2006):

$$\frac{\left[\left(\dfrac{\text{Installed Cost}}{\text{Desired Simple Payback}}\right) + \text{Annual Cost}\right]}{\%\ \text{Annual Savings}} = \text{Minimum Annual Electric Bill}$$

where

- *Installed Cost* refers to the total cost to purchase, install, and commission the meter. As previously noted, the cost of a meter application will vary based on a number of factors. Building electric meters are often in the range of $1,500 to $5,500 completely installed.

- *Desired Simple Payback* represents the number of years it will take the metering system to produce (lead to) cost savings equal to the installed cost. In the federal sector, the simple payback period should be 10 years or less.

- *Annual Cost* is the total annual cost of the fees and expenses to cover communications, data collection and storage, and data analysis, as well as meter operations and maintenance. The annual cost will vary based on several factors and is typically in the range of $120/year ($10/month) to $600/year ($50/month).

- *% Annual Savings* is the estimated cost savings benefits to be realized from the productive use of the metered data. Federal sites are advised to use a minimum 2 percent annual savings when considering meters for EPAct compliance.

Installed Cost refers to the total cost to purchase, install, and commission the meter.

Using the above formula also requires that there be a reasonable way to estimate the current annual electricity (utility) costs for the building being considered. Except in cases where the buildings already have standard meters, actual usage data to estimate the annual costs will not be available. In these cases, one of the following accepted methods of estimating building energy use should be applied:

- Square footage
- Energy-use intensity
- Calibrated software
- Short-term metering

Accepted Methods of Estimating Building Energy Use

The four accepted methods of estimating building energy use for cost-justifying meter applications are as follows:

Square Footage: This method estimates energy use by first dividing the total site use by the total site square footage, and multiplying the quotient by the building square footage. This results in a cut-off point for size of buildings for which meters will be applied. *Benefits*: This approach is quick and simple. *Challenges:* The approach is not very accurate as decisions do not take into account the uses of energy within the individual building. For example, a small energy-intensive building used for research and development or food service might not be metered while a large, unconditioned, low-energy-consumption warehouse would.

Energy-Use Intensity (EUI): The EUI method involves estimating a kWh per square foot per year (kWh/ft^2/yr) value for each building being evaluated. EUIs will vary (primarily) by the building use and climate zone. *Benefits*: When good data are available, this method can be quickly used with relatively accurate results. *Challenges*: Obtaining site-specific EUI data. Sources of EUI data include:

- Commercial Buildings Energy Consumption Survey (CBECS) data at http://www.eia.doe/gov/emeu/cbecs/content.html
- DOE Buildings Energy Data Book at http://buildingsdatabook.eren.doe.gov

Calibrated Software: This method involves running software simulations to calculate building energy use. Accepted building simulation software includes EnergyPlus and DOE-2. Sites interested in using a multi-building software analysis approach can use the Facility Energy Decision System (FEDS) to complete a site-wide analysis for energy efficiency opportunities and metering practicability. *Benefits*: Calibrated software can provide accurate results, and models/files may be used to support retrofit project identification. *Challenges*: Populating the software with site data.

Short-Term Metering: This method relies on making use of metering equipment to take short-term meter readings to estimate annual building energy use. *Benefits*: When done properly, this approach can produce very accurate estimates. *Challenges*: This approach requires metering equipment, and time to collect and analyze the data.

There are four accepted methods of estimating building energy use for cost-justifying meter applications.

To demonstrate how the metering cost justification formula is used, the following values will be used:

- Installed cost = $5,000
- Desired simple payback = 10 years
- Annual cost = $25/month = $300/year
- % annual savings = 2 percent

Sample calculation: (NOTE: The values in this sample are for demonstration purposes only.) Sites considering metering applications should use values specific to their site.

$$\frac{\left[\left(\dfrac{\text{Installed Cost}}{\text{Desired Simple Payback}}\right) + \text{Annual Cost}\right]}{\%\ \text{Annual Savings}} = \text{Minimum Annual Electric Bill}$$

= [($5,000) ÷ (10 years) + $300/year] ÷ (0.02)

= $40,000 minimum annual electric bill

In this example, an electric meter application will be cost-justified if the building's annual electricity use is more than $40,000.

As previously mentioned, the results from this equation are sensitive to the input variables. Figure 8.1 demonstrates how the minimum annual electric bill for cost-justified applications becomes smaller as the annual savings percentages increase, while the installed and annual costs and the simple payback period are held constant. Likewise, similar curves can be developed for varying other variables such as the cost of the meter, or changing combinations of variables such as annual percent savings and the cost of the meter.

Identifying the proper financing approach is a critical step in the successful implementation of a metering program.

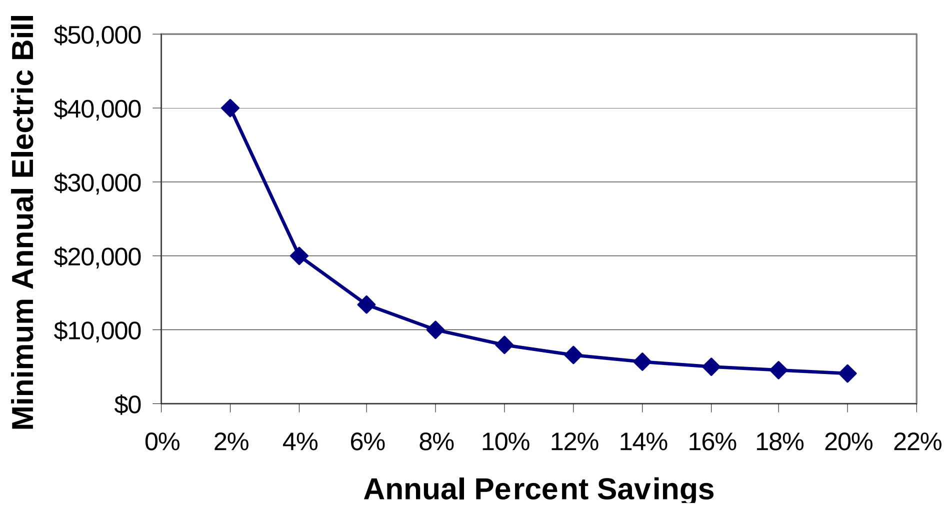

Figure 8.1. Minimum Electric Bill versus Annual Percentage Savings ($5,000 installed cost)

8.5 Financing Options

Identifying the proper financing approach is a critical step in the successful implementation of a metering program. The selected financing option, or options, will impact the overall system design and its capabilities, as well as the installation timeline. Since there are many financing options available to the federal sector, the financing approach used at a given site should be selected based on site-specific needs and opportunities.

8.5.1 Metering System Purchasing and Installation Financing Approaches

There are a number of potential financing alternatives available to federal sites. Factors affecting the financing alternatives available include estimated system cost, agency policies, and utility company support offerings, to name a few. In some cases, sites will be able to finance their metering systems through a combination of approaches, while in other cases they may be limited to single options.

8.5.1.1 Metering Financing Hierarchy

As a way for sites to begin their initial considerations of financing alternatives, the financing hierarchy has been developed (Figure 8.2). This hierarchy is based on life-cycle costs to the site's facility, utility, or energy management program as many consider life-cycle costs to be the most significant factor in selecting their financing approach. Additional hierarchies may be developed based on factors such as speed of implementation or lowest first/up-front cost. Note that a lowest first cost approach may allow for faster implementation or a metering program with expanded capabilities.

Factors affecting the financing alternatives available for metering include estimated system cost, agency policies, and utility company support offerings.

The Metering Financing Hierarchy

"No-Cost" Options:
- Policy-directed approaches
  - Include in construction and renovation projects
  - Assess tenant fees
  - Reinvest energy savings
- Utility provided (for time-based rates customers)

Appropriations Options:
- Line item appropriations
- Locally managed appropriations

Alternative Financing:
- Utility company financing
- Energy savings performance contracts (ESPCs)

Figure 8.2. The Metering Financing Hierarchy

Two key assumptions are applied to this hierarchy:

- Recurring costs (system operations and maintenance) are the same for all of the approaches.
- Resulting energy savings are the same regardless of the financing approach.

Including the up-front and/or installation costs of metering in construction and renovation projects is recommended for all agencies and sites.

The approaches addressed at the top of the hierarchy are the so-called "no cost" options. This is not to imply that the meters are free: instead, the costs to purchase and install the meters are covered in part or in total by programs other than the site facilities, utilities, or energy program.

The appropriations approaches are next in this hierarchy's order. While the costs for the metering system are now being incurred by the site or agency facilities programs, agency appropriations are a familiar approach where the total costs of the meters are paid at the time of purchase and installation.

Alternatively financed approaches appear at the bottom of this hierarchy since the overall life-cycle costs are higher than the appropriations approaches due to added financing charges. This is not to imply that these approaches are any less likely to succeed than the other options. Site metering opportunities at some sites may benefit from alternative financing as a way expand the metering system or add capabilities beyond the EPAct requirements.

8.5.1.2 Descriptions of Financing Approaches

The first options to consider are those for which the up-front purchase and/or installation costs of metering are covered entirely or in-part by funding sources outside the (direct) facilities, utilities, or energy program budgets.

Include in Construction and Renovation Projects

- Description: Require by site (or agency) policy that meters be included in all new building construction and major renovation projects.

- Benefits:
  - The cost of the meter is assumed as a (very) small part of the overall project budget
  - A separate metering project is not required for new buildings

- Disadvantages:
  - Meters might be lost to value-engineering. Metering program manager must track inclusion of meters from start of project (initial funding request) through completed construction.
  - New construction represents a very small part of the federal building inventory on an annual basis. Sites will still need to address metering requirements at remaining buildings.

- Where to use: This approach is recommended for all agencies and sites.

- Additional considerations: The DoD Instruction 4170.11 establishes the requirement that meters be included in all new building and major renovation projects exceeding $200,000. Metering requirements cover electricity, natural gas, and water.

Assess Tenant Fees

- Description: Include the cost to purchase, install, maintain, and operate the metering system as part of the tenant rental rates.

- Benefits:
  - Tenant assessments are already in place at many sites
  - Meters will allow for billing tenants for their actual energy/utility use. Tenants will then have greater incentive to reduce use.
  - Funding approach can address post-installation metering system operations and maintenance financing requirements.

- Disadvantages: Tenant buy-in for additional assessment fees may be difficult to obtain.

- Where to use: Multi-tenant sites where utility cost allocation is being practiced or considered.

- Additional considerations: This approach can also be used in at multi-tenant single building sites.

Reinvest Energy Savings

Reinvesting energy savings in a metering program can offset the requirements for appropriations funding.

- Description: Per EPAct 2005, agencies may retain funds not expended because of energy or water savings, provided that these funds further promote energy efficiency, water conservation, or unconventional and renewable energy resources projects. Metering equipment leading to additional energy savings is then an eligible investment for retained energy savings.

- Benefits:
  - Reinvested energy savings can offset the requirement for appropriations funding.
  - Competition for these funds is limited to energy and water efficiency measures.

- Disadvantages:
  - Retention of savings will be addressed on an agency-by-agency basis.
  - Sites will likely need to document sources of savings when determining funds available for retention.

- Where to use: When these funds are available and when the metering system is being installed using appropriated dollars.

- Additional considerations: From a planning perspective, it will be difficult to estimate future funding streams available for reinvestment because

Data analysis may be provided by the utility; however, sites may still need to complete their own data analyses to support site-specific data use activities.

funding amounts will be impacted by a number of factors such as other ongoing efficiency measures, weather, and operational requirements.

Retention of Energy and Water Savings

EPAct 2005, Section 102, paragraph (f), Retention of Energy and Water Savings, amended section 546 of the National Energy Conservation Policy Act (42 U.S.C. 8256) as follows:

> "(e) Retention of Energy and Water Savings.—An agency may retain any funds appropriated to that agency for energy expenditures, water expenditures, or wastewater treatment expenditures, at buildings subject to the requirements of section 543(a) and (b) [energy reduction goals], that are not made because of energy savings or water savings. Except as otherwise provided by law, such funds may be used only for energy efficiency, water conservation, or unconventional and renewable energy resources projects. Such projects shall be subject to the requirements of section 3307 of title 40, United States Code [Congressional approval of proposed projects]."

While EPAct allows agencies to re-apply these funds for additional energy and water efficiency measures, it is up to each individual agency to determine if such a re-investment will be allowed and any procedures to be followed.

Utility-Provided Meters

- Description: Customers requesting to be placed on time-based electric rate schedules may receive an advanced meter from their servicing utility.
- Benefits: Meter is provided at no cost.
- Disadvantages:
  - Time-based rates are not universally available.
  - Time-based rates may not be the best rate tariff option available to the site.
  - Customers will likely be limited to one meter per account.
- Where to use: Use at all sites where a time-based rate tariff is or will be in effect.
- Additional considerations:
  - Site may need to work with the utility to access the data in real-time or near-real-time.
  - Data analysis may be provided by the utility; however, sites may still need to complete their own data analyses to support site-specific data use activities.

- Caution: Do not disaggregate loads at multi-building sites for the purpose of obtaining additional meters from the electric utility as this would work to create multiple smaller customers that would be subject to less favorable rates.

Time-Based Rates (DOE 2006) (EPAct 2005)

Section 1252 of EPAct, Smart Metering, requires that within 18 months of enactment [by February 2007] that states investigate and decide whether to mandate utilities to offer to each customer a time-based rate schedule under which the rate charged by the electric utility varies during different time periods and reflects the variance, if any, in the utility's costs of generating and purchasing electricity at the wholesale level. The time-based rate schedule would enable the electric consumer to manage energy use and cost through advanced metering and communications technologies. If the states mandate time-based rate schedules, each electric utility would provide each customer requesting a time-based rate with a time-based meter capable of enabling the utility and customer to offer and receive such a rate, respectively.

Types of time-based rates include

- **Time-of-Use (TOU) Pricing**: Energy prices that are set for a specific time period on an advance or forward basis, typically not changing more often than twice a year (summer and winter season). Prices paid for energy consumed during these periods are pre-established and known to customers in advance of such consumption, allowing them to vary their demand and usage in response to such prices and manage their energy costs by shifting usage to a lower cost period, or reducing consumption overall. The time periods are pre-established, typically include from two to no more than four periods per day, and do not vary in start or stop times.

- **Critical Peak Pricing**: A type of dynamic pricing whereby the majority of kWh usage is priced on a time-of-use basis, but where certain hours on certain days where the system is experiencing high peak demand are subject to higher hourly energy prices that reflect market conditions for peak generation and delivery during peak demand periods. These critical period prices may be known to electricity customers under conditions as "day-ahead" or "hour-ahead" and are typically employed a limited number of times per year.

- **Real-Time Pricing**: Energy prices that are set for a specific time period on an advance or forward basis and that may change according to price changes in the generation spot market. Prices paid for energy consumed during these periods are typically established and known to consumers a day ahead ("day-ahead pricing") or an hour ahead ("hour-ahead pricing") in advance of such consumption, allowing them to vary their demand and usage in response to such prices and manage their energy costs by shifting usage to a lower cost period, or reducing consumption overall.

There are no long-term commitments for repayment or performance-based requirements that must be monitored with line item appropriations for funding metering projects.

Line Item Appropriations

- Description: Metering projects are funded through the agency's line item appropriation. Funds are then distributed to the sites by the agency.

- Benefits:
  - Federal agencies and sites are familiar with this funding approach.
  - There are no long-term commitments for repayment or performance-based requirements that must be monitored.

- Disadvantages:
  - Metering must compete against other initiatives for funding.
  - It can take several years from the time of the initial funding request to the time that the funds are actually available to the site.
  - Initial cost estimates are important as funds received set an overall cost cap.

- Where to use: Use at sites as directed by the agency.

- Additional considerations:
  - Federal sites should inquire within their agencies if line item appropriations will be sought and when they will be available. Several agencies have adopted this approach – the General Services Administration and the Department of the Army in particular.
  - Agency appropriations may apply meeting certain requirements such as EPAct (building electric) or DoD Instruction 4170.11. Metering programs that intend to address metering beyond the legislated or mandated requirements may need to identify additional funding sources.

Locally Managed Appropriations

- Description: Sites use funds from locally managed accounts such as utilities or small projects.

- Benefits:
  - Federal sites are familiar with this funding approach.
  - The level of effort required to obtain local funding, especially "small" amounts, may be easier and faster than obtaining funds from the other available approaches.
  - Appling locally managed funds allows for incrementally building a metering system.

- Disadvantages: Metering projects must compete against other local projects for funding.

- Where to use:
  - Especially well suited for sites where metering costs are expected to be small.
  - Do not use local funding if agency line item funding is available unless additional funds are needed to increase system capabilities (i.e., equipment monitoring, building sub-metering, and utilities other than electricity).

- Additional considerations: Agencies may prefer this approach over the line item approach since using locally managed funds allows the sites to prioritize metering against other facilities needs.

Utility Company Financing

- Description: Servicing utility company finances the purchase of the meter or services in support of a metering program internally or through a third party, with repayment back to the utility as part of the monthly bill.

- Benefits:
  - Over the years, many federal sites have installed energy efficiency measures by using utility financing.
  - Utility financing for projects and services can be used for small projects (several hundreds of dollars) and large projects (millions of dollars) alike.
  - Services supporting other metering program needs can also be financed:
    - Engineering services such as surveying existing systems and designing new systems.
    - The purchase and installation of meters.
    - Monthly services including meter maintenance and data analysis.
  - Several approaches are available to federal sites that want to work with their servicing utility: Areawide contracts, basic ordering agreements, and rebates.
    Visit the FEMP Utility program website at http://www1.eere.energy.gov/femp/financing/uescs_types.html for a description of the available utility financing approaches.

- Disadvantages:
  - Utility financed projects will be assessed interest fees.
  - Not all utilities offer financing assistance.
  - Sites need to make sure that money is available to cover the added financing cost included in the utility bill. Ideally, these funds will be available from the offsets realized by reduced utility cost savings.

- Where to use:
  - Always take advantage of available rebates that support your metering program goals and objectives.

Always take advantage of available rebates that support your metering program goals and objectives when it comes to utility company financing.

ESPCs are available to all federal sites. Consider using an ESPC when appropriated funds are not available.

   - Consider using when appropriations are not available or if the availability of utility financing presents a significant time advantage (accelerated savings) over appropriated dollars.

- Additional considerations: Sites may want to consider financing the installation of a metering system in conjunction with additional energy efficiency projects when utility financing is used.

Energy Savings Performance Contracts (ESPCs)

- Description: Install meters/metering system as part of an ESPC. There are two approaches by which this can be accomplished:
  - Install the meters as an energy conservation measure (ECM) under the ESPC. In this case the savings will be stipulated since the resulting savings occur in response to the metered data and its analysis, not the meters themselves.
  - Install the meters in support of or as part of an ECM. Key to this approach is ensuring that energy savings are realized and that they can be verified. Examples of this approach include
    - Using interval data as part of an ongoing retro-commissioning activity
    - Using interval data to support of actions completed by the ESPC contractor such as real-time purchasing, peak load management, equipment diagnostics, and electric rate comparisons.

- Benefits:
  - ESPCs are available to all federal sites.
  - The ESPC contractor can assume the data analysis function and reporting.

- Disadvantages:
  - ESPC costs include finance charges, contract overhead fees, and measurement and verification expenses.
  - ESPCs typically require an overall project investment of no less than $500,000 dollars.

- Where to use:
  - Consider using an ESPC when appropriated funds are not available
  - ESPCs are well suited for federal sites that want to include a number of ECMs, especially if the site would like to have all the metering program functions contracted.

- Additional considerations:
  - It is strongly recommended that the ESPC assign to the contractor the data analysis functions, and that there are provisions for taking actions resulting from the analysis findings and recommendations.

– While the measurement and verification (M&V) for some ESPCs requires metering, this metering is typically applied to specific equipment. In these cases, the metering system should incorporate this metered data provided it supports a metering program objective. However, M&V metering supports the EPAct requirements only when whole-building electrical metering is used.

The National Institutes of Health in Bethesda, Maryland (Figure 8.3) embarked on a complex-wide ESPC focused on meters and metering systems. This activity is highlighted in the Case Studies section (Chapter 9) of this guide. Visit the Federal Energy Management Program's ESPC website for information on ESPCs: http://www1.eere.energy.gov/femp/financing/superespcs.html

Figure 8.3. The National Institutes of Health in Bethesda, Maryland, is using an ESPC to install over 350 meters across the complex.

Selecting a financing approach is site specific as there are a number of factors that will influence your decision.

8.5.2 Selecting a Financing Approach

Selecting a financing approach is site specific as there are a number of factors that will influence the decision:

- What are the site's metering needs?
- Are there agency policies affecting systems capabilities such as reporting requirements and financing approaches? For example, some agencies are financing their installations through line item appropriations, while others may direct the sites to first contact their local utility to see if there are any financial or technical assistance offerings.
- What is the current and projected availability of funds at the agency and site levels?
- What financial and technical assistance does the servicing electric utility offer?

- Does the site have the staff resources to commit to completing data analyses in a timely manner? What about the ongoing repair and maintenance of the metering system components?
- Does it make sense to consider installing a metering system as part of a larger site-wide energy efficiency project?

8.5.3 Metering System Operations and Maintenance Financing

The up-front costs to purchase and install a metering system tend to generate the most attention when sites are planning their metering programs. However, the success of the metering program depends on the quality of the data collected and its ***productive application***. Sufficient funding for the continuing operations and maintenance of the metering program must be in place once the metering system components are in operation. Funds to support the metering program will likely need to be identified from the facilities operations budget, and will cover a range of expenses including the ongoing operation of the meters, data storage, data analysis, and reporting/communications.

The success of the metering program depends on the quality of the data collected and its productive application.

8.6 References

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Chapter 9 Federal Sector Case Studies/ Success Stories

9.1 Electric Metering Program at Brookhaven National Laboratory

Brookhaven National Laboratory (BNL), centrally located on Long Island, New York, is a multi-program national laboratory operated by Brookhaven Science Associates for the U.S. Department of Energy (DOE), and employs over 2,700 people. Major research programs resident at the laboratory include

- Nuclear and high-energy physics
- Physics and chemistry of materials
- Environmental and energy research
- Nonproliferation
- Neurosciences and medical imaging
- Structural biology

Brookhaven National Laboratory's metering program began in the mid-1980s in response to the installation of new buildings and energy-intensive process loads.

Electricity is purchased on the real-time market by the hour using the New York Power Authority (NYPA) as its purchasing agent and is transmitted to the laboratory by the Long Island Power Authority (LIPA). The annual electric bill for fiscal year 2006 was $16 million, with consumption exceeding 241 GWh. The average blended cost of electricity to the site is 6.5 cents per kWh. However, hourly prices for electricity can exceed $1/kWh during certain periods. Further, the impact from demand charges is over $100,000/MW-year.

The BNL metering program began in the mid-1980s in response to the installation of new buildings and energy-intensive process loads. The addition of new buildings and additional process loads (e.g., supercomputer installations) continues today, all contributing to the already large site electricity bill.

The initial objective of BNL's metering program was to better control electric demand and energy use through billing the resident programs for their actual electric use (cost allocation). Approval of the metering program was based on the idea of controlling electricity costs due to increasing energy use by identifying areas of increasing consumption and validating cost savings from energy conservation measures.

Two main metering projects at BNL were funded by DOE in the 1980s. Since that time, all metering expenses have been covered by site operating funds.

BNL currently has over 200 electric meters onsite metering building loads, substations, individual transformers and process loads. Pulse data from the electric meters are stored in digital data recorders. The data recorders are interrogated on a daily basis by a meter data retrieval program via an analog phone line connection. The data are stored on a server, which is then used for monthly bill calculations, load analysis, and database input.

Figure 9.1 is used by BNL to present a monthly summary comparison of the actual site electric load to the planned site electric load. Electric load planning and management are critical activities at BNL as the site purchases all its electricity in the day-ahead market. Deviations from the scheduled usage are either purchased or sold in the real-time market where prices can fluctuate dramatically. In this case, the scheduled load is an estimate of the daily loads by hour. The consumption data are also presented on an hourly basis. Consumption and cost data are reviewed on a daily basis, and this information is made available to site tenants via a website.

The ability to monitor demand loads saves BNL "well over $1 million per year."

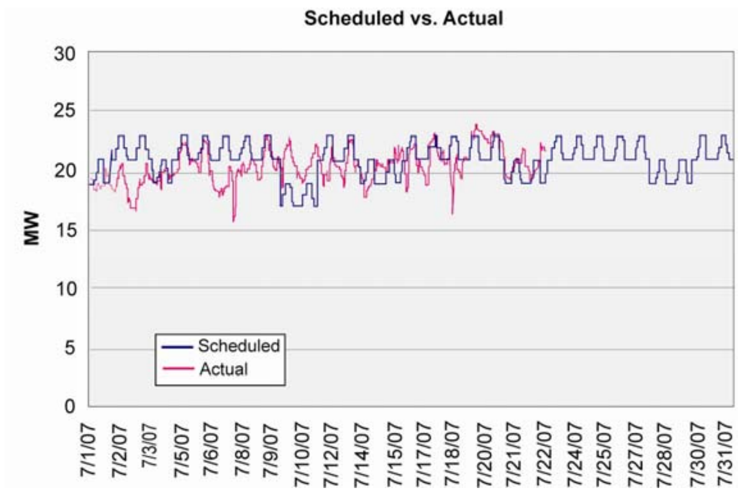

Figure 9.1. Monthly Summary of Scheduled vs. Actual Site Electric Demand Loads

Benefits in the form of cost savings resulting from the BNL metering program have not been documented over the course of the program's life. However, site staff offer the following observations:

- Electric consumption of one tenant dropped 40 percent when the tenant was billed for actual consumption. BNL has noticed similar behaviors when billing tenants for actual chilled water and potable water consumption.
- The ability to monitor and control demand loads saves the site "well over $1 million per year."

Lessons Learned:

- The metering system at BNL has allowed the site the flexibility to purchase electricity at the most favorable time-based rates, leading to significant savings.

- Load management in support of electricity procurement can be done at a large, multi-building site.
- Allocating costs to tenants on the basis of actual use can lead to significant modifications in behavior and use.
- Data captured by the electric meters are also used by electrical design engineers to properly size replacement transformers, generators, and conductors.

9.2 General Services Administration's Kastenmeier Federal Courthouse

In 2005, the operations staff at the Kastenmeier Federal Courthouse in Madison, Wisconsin, agreed to serve as a pilot site for the demonstration of the newly developed web-enabled Whole-Building Energy Diagnostician (WBE). The WBE was originally developed by the Pacific Northwest National Laboratory (PNNL) with funding from the U.S. Department of Energy's (DOE's) Building Technologies Program. In an effort to make the tool more affordable and more widely available to the federal sector, DOE's Federal Energy Management Program (FEMP) funded the development of a web-enabled version of the WBE. The WBE module installed at the Kastenmeier Federal Courthouse was a commercialized version of the tool.

The Whole-Building Energy Diagnostician tracks energy uses at the building level – in this case, the total electric and natural gas use in General Services Administration's Kastenmeier Federal Courthouse.

The WBE module tracks energy uses at the building level – in this case, the total electric and natural gas use. The values of expected energy consumption are generated by empirical models of the building, which are automatically developed by the WBE. In general, the model uses time of week, outdoor air dry-bulb temperature, and relative humidity as independent variables. The WBE then graphically provides building operators alarms for unexpected usage to identify major changes in energy consumption (PNNL 2005).

As part of the demonstration project, NorthWrite, Inc., partnered with FEMP to make the web-enabled WBE module available to the Madison Courthouse as part of an overall suite of operations and management tools. The Madison Courthouse is a 100,000-square-foot building in Madison, Wisconsin. The building spaces include court rooms, chambers for the judges, jury rooms, holding cells, and offices for the Clerk of Courts, Bankruptcy Courts and U.S. marshals. Daily building occupancy includes approximately 120 full-time employees plus daily visitors.

The one-year demonstration started in May 2005 with the installation of the electric pulse meter and a monitor device, which reads pulse outputs from the meter and sends them wirelessly to a network operations center, needed to support the web-enabled WBE (Figure 9.2). A gas pulse meter was installed in

July 2005. Summary of costs to purchase, install, and operate the metering system at the Kastenmeier Federal Courthouse is as follows:

- $1,000 to purchase and install the electric and gas meters (approximately $500 each)
- $3,500 to install the proprietary WBE-based tool hardware
- $2,500 to train agency staff on the use of the commercial web-based suite of tools (which included the WBE-based tool as well as additional site maintenance management functionality)
- $100 per month for the monitor service
- $250 per month to subscribe to the WBE-based tool and commercial maintenance management services suite of tools.

The reports and graphics generated by the Whole-Building Energy module are reviewed daily by the building mechanic as part of the morning startup.

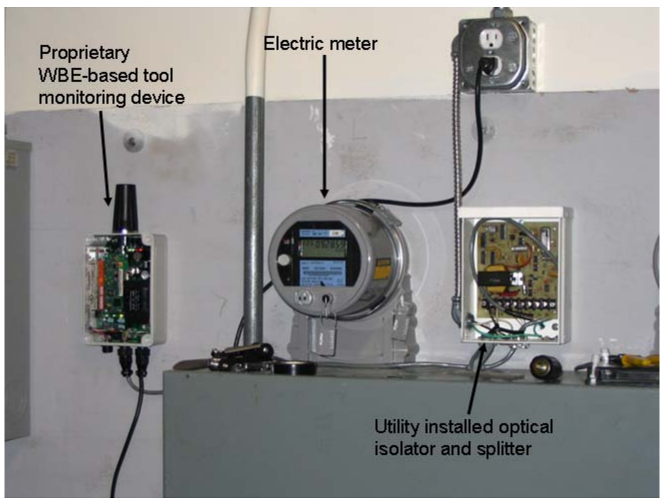

Figure 9.2. Installed Wireless Monitoring System for WBE-based System (Photo courtesy of NorthWrite, Inc., Minneapolis, MN.)

The reports and graphics generated by the WBE module are reviewed daily by the building mechanic as part of the morning startup, with an emphasis on verifying that peak usages do not vary unexpectedly (Figures 9.3 and 9.4). These daily reviews of the data have been helpful in diagnosing:

- Incomplete reprogramming of schedules on the building automation system (BAS) following a time change
- Improper boiler sequencing operations
- An air-handler operating 24/7 instead of on the schedule as programmed by the BAS
- Belt slippage due to wear on a large horsepower motor

- Refrigerant leaks in rooftop compressors.

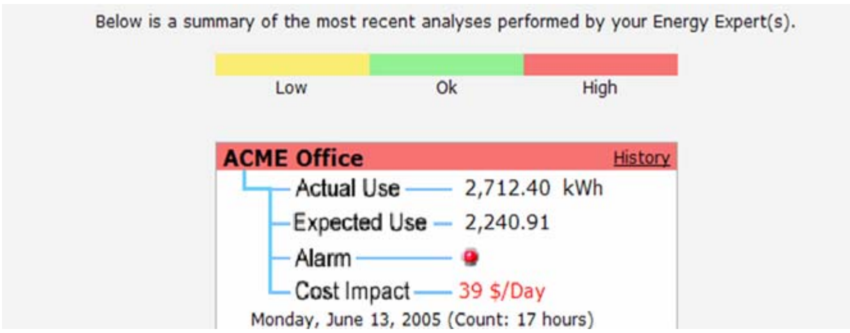

Figure 9.3. Sample Screen Capture for a Generic Building Showing an Alarm or High-Energy Using Condition. Included is an estimated cost impact associated with the higher than expected electricity use. (Screenshot courtesy of NorthWrite, Inc., Minneapolis, MN.)

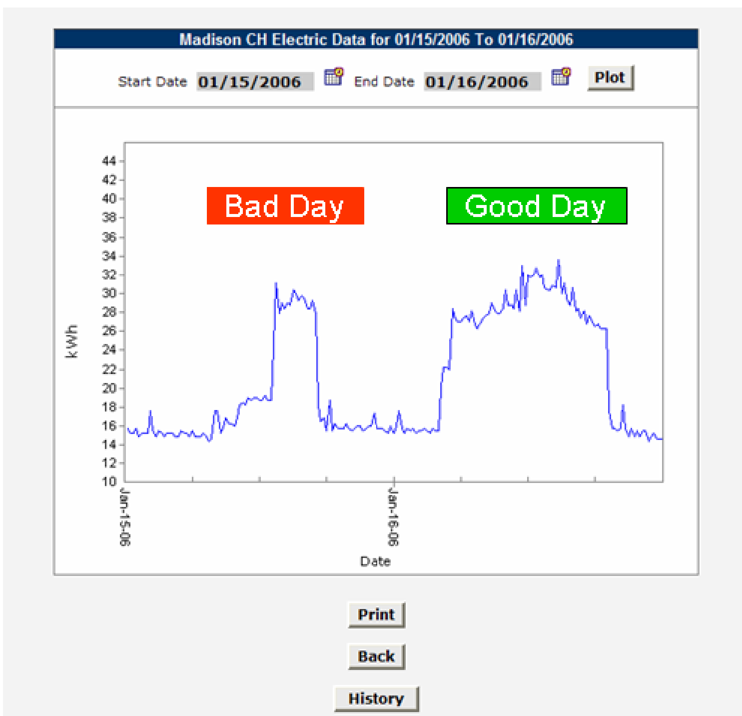

Figure 9.4. Data from the Monitoring Device Provides a Comparison of 2 Days of Electricity Use for Sunday, January 15, 2006, and Monday, January 16, 2006. Figure shows unexpected off-hour usage on the 15th, while electricity consumption on the 16th was as expected. (Screenshot courtesy of NorthWrite, Inc., Minneapolis, MN.)

The Whole-Building Energy Diagnostician has been helpful in identifying problems such as improper boiler sequencing operations and refrigerant leaks in rooftop compressors.

The WBE module also lets the General Services Administration (GSA) staff

- Observe the effects of variable-speed drives and direct-expansion cooling operations, including occasional spikes in electrical consumption

- Verify that energy-intensive IT downloads are completed during off-hours.

Since this is a web-based system, the GSA regional energy office in Chicago is able to access and review the system data. This second set of eyes works to alert the Madison staff of other possible emerging trends.

Lessons Learned:

- Metered data were instrumental in identifying high or abnormal energy use, and assisted in diagnosing inefficient equipment and systems operations at the Kastenmeier Federal Courthouse.
- The ability to view data at multiple, including remote, locations allowed for expanded assessment capabilities.
- Metering natural gas consumption, while not required by EPAct, proved beneficial.
- The application services provider model allowed for expanded functionality through the offering of additional facilities management tools.

GSA's building inventory includes 179.7 million square feet of building space located nationwide that is tracked for compliance with the federal energy reduction goals.

9.3 General Services Administration's Enterprise-Based Metering System

(Curran 2007)

The General Services Administration's (GSA's) Public Buildings Service is the largest real estate organization in the country. The GSA building inventory includes 179.7 million square feet of building space located nationwide that is tracked for compliance with the federal energy reduction goals. This goal inventory accounts for over $300 million in annual energy expenditures and includes over 880 facilities ranging from 817 square feet to 4.2 million square feet.

Efforts to establish and deploy an agency-wide metering system began in response to a 2004 Government Accounting Office (GAO) audit on demand response programs.[2] In this report, the GAO found that participation in demand response programs by the GSA at a limited number of buildings had resulted in significant savings, and concluded that agency-wide participation in such programs would have resulted in significantly greater savings. The GAO audit,

[2] www.gao.gov/cgi-bin/getrpt?GAO-04-844.

along with the soon-to-follow EPAct 2005 metering requirements, provided the impetus for GSA to develop and deploy an agency-wide metering system that could address a variety of energy management – use, procurement, and reporting – issues:

- Provide real-time interval data for energy use diagnostics
- Trend building electricity use on daily, monthly, and yearly basis
- Establish and manage peak demand usage where ratchet charges are in effect
- Promote participation in demand response program offerings
- Assist in aggregating load profiles for competitive power procurements
- Aggregate electricity use data on a national basis
- Integrate data from metering systems already in-place across GSA.[3]

Per EPAct requirements, GSA will eventually install advanced meters at all buildings where cost-effective. Applications are prioritized by the GSA regional managers primarily on the basis of several cost and usage metrics. Additional factors considered in the prioritization process include high profile regional issues, current or planned use of energy savings performance contracts, multiple building facilities with shared heating and/or cooling plants, and verification of project savings. Funding for the meters and their connection to the agency software program is provided largely through the annual budget, although GSA seeks to leverage costs by also including meters as part of ongoing projects as well as available meter offerings on the part of servicing utilities.

Per EPAct requirements, GSA will eventually install advanced meters at all buildings where cost-effective.

Decisions on what meters to use are made by GSA regional staff. Data from the meters/sites are communicated to the centralized system through Modbus TCP/IP-compliant protocol. From there, the GSA metering system's enterprise energy management software provides the data storage, analysis, and reporting. This enterprise energy management software was developed under contract for GSA by a meter manufacturer, and resides on a server behind the GSA firewall. Figure 9.5 presents a sample output interface at one of the connected buildings.

The GSA's agency-wide metering system is at this time a work in progress as the installation of meters across the GSA building inventory and integration of the meters into the centralized system will take several years. Still, the GSA is able to cite some early uses and successes resulting from this program:

- Increased participation in voluntary demand-side load curtailment and price response programs, as well as contracted demand response programs (where agreed upon demand loads cannot be exceeded without incurring penalties).

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[3] There were already several metering systems in place within GSA when planning for the enterprise-based metering system began. These separate metering systems at the site and regional level may tap into additional functionality of the enterprise-based metering system should they so desire.

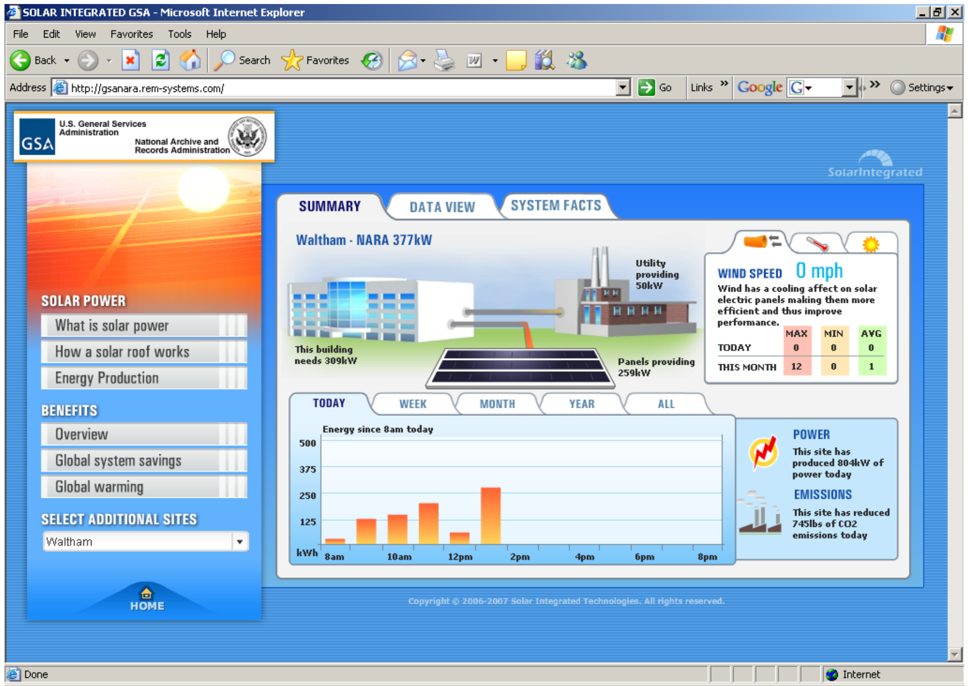

Figure 9.5. Summary of Current Conditions at a GSA Building in Waltham, MA. Data include current building demand, PV production, and utility supplied electricity. This website provides real 15-minute data and can be accessed at http://gsanara.rem-systems.gov

- Development of data on energy savings realized in support of congressional testimony.
- Verification of ability to react to load and price conditions using metering technology and pre-determined load shedding plans.
- Demonstration in real-time the actual production of electricity and resulting savings from a rooftop PV application in Waltham, MA.

Lessons Learned:

- Centralized energy data use and reporting is a viable approach that can provide timely data at the site or headquarters levels.
- Compliance with and administration of Homeland Security Presidential Directive (HSPD) 12 – Policy for a Common Identification Standard for Federal Employees and Contractors,[4,5] has proven to be challenging, and is credited with creating significant implementation delays. It is recommended that sites/agencies understand agency HSPD 12 requirements and processes as they begin planning their metering systems.

Centralized energy data use and reporting is a viable approach that can provide timely data at the site or headquarters levels.

[4] http://www.whitehouse.gov/news/releases/2004/08/20040827-8.html
[5] http://www.whitehouse.gov/omb/memoranda/fy2005/m05-24.pdf

- Large (nationwide) metering systems can create significant new system maintenance requirements. Support requirements from Information Technology staff needs to be identified up-front and budgeted.

- Interval metering at the building level allows GSA to increasingly participate in contracted electric demand management programs that carry greater financial incentives than the voluntary load curtailment programs. Participation in these programs is possible, in part, because there is an ability to better understand the load reduction commitment against current load requirements. Also, (near) real-time data make it possible for building operators to monitor their electric demand loads during the curtailment periods.

9.4 National Institutes of Health Headquarters

(Leifer 2007)

The National Institutes of Health (NIH) is the primary federal government agency for conducting and supporting medical research. The NIH headquarters campus is located in Bethesda, Maryland. This campus includes over 10 million square feet of building space to support hospital, research, laboratory, industrial, and office uses. And as expected for a facility that houses medical research, the utility costs resulting from high-intensity uses are quite large: $75 million in fiscal year 2005, and nearly $95 million in fiscal year 2006. In an effort to better manage their utility costs, the NIH determined that a facility-wide metering program would be effective in

- Understanding utility use at the building level
- Monitoring and managing utility use and costs
- Diagnosing utility use problems.

The National Institutes of Health metering system consists of over 350 meters. Over 200 of these are electric meters.

The NIH metering system consists of over 350 meters. Over 200 of these are electric meters while more than 150 are non-electric meters for steam, chilled water, and domestic water. Figures 9.6 and 9.7 show NIH's chiller water metering and compressed air metering systems. Because of the size and complexity of the system, the purchase and installation of the meters is being done as part of a larger energy savings performance contract (ESPC). In this case, the energy savings from the meters are stipulated in the ESPC contract, as opposed to supporting specific energy conservation measures such as ongoing commissioning or real-time purchasing of electricity.

Figure 9.6. Chiller Water Metering at NIH. Photo on left shows water supply and return pressure sensors; photo on right is a chiller water meter energy/flow processor.

Figure 9.7. Compressed Air Meter Applications at the NIH. Meter in left photo is an insertion-type while meter in right photo is an in-line-type.

> *In the National Institutes of Health metering program, electric meters chosen for application at substations were "higher-end" while "lower-end" electric meters were used at buildings.*

Features/characteristics of the metering system include the following:

- Electric meters chosen for application at substations were "higher-end" while "lower-end" electric meters were used at buildings.
- Insertion meters were used for steam, but ultrasonic meters were used for chilled water applications because of ease of installation (non-intrusive technology and piping bypasses not needed) and maintenance and calibration.
- Communications are handled through two different approaches:
  - A separate SCADA system on a local area network is used for the electric meters
  - The building automation system (BAS) is used for non-electric meters
- Data storage and analysis is done onsite.

The installation of the metering system is not yet complete. However, Figure 9.8 demonstrates an early success of the metering program in helping to identify excessive steam use in a building. In this figure:

- the x-axis is the time in increments of 1.5 hours (labels on 6-hour increments)
- the y-axis is pounds of steam per hour
- the top line plot is the steam plant generation for the NIH campus
- the lower line plot is the steam demand for a single 270,000-square-foot building.

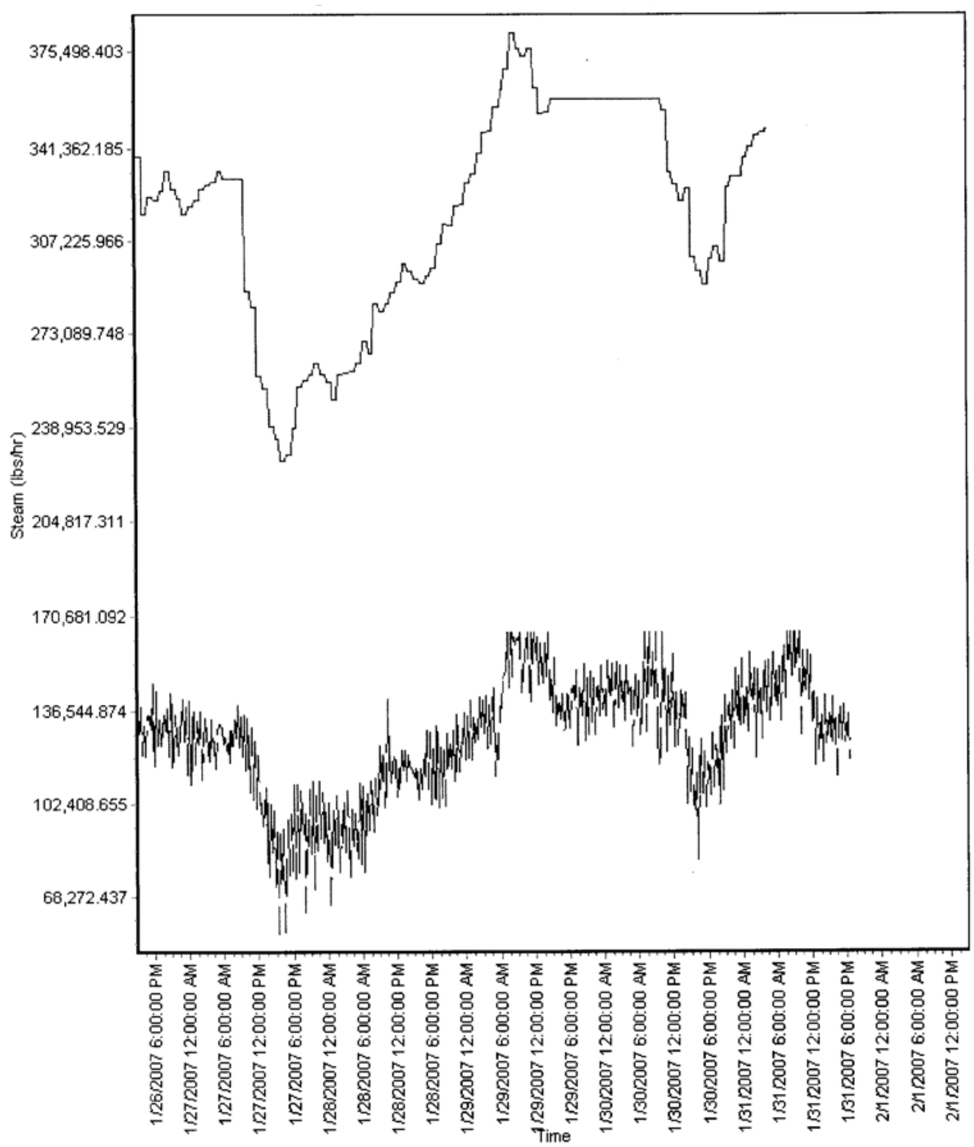

Figure 9.8. Total Site Steam General vs. Single Building Steam Demand

A quick review of Figure 9.8 shows that the single building steam use accounted for approximately 30 percent of the total site steam use, even though the building accounted for roughly 2.5 percent of the total site building square footage. The first action taken by the site was to verify the accuracy of the building steam meter. The NIH staff then inspected the building's steam systems and flow and found that the metered data appeared to be reasonable. The next step (currently ongoing) is to assess the building's systems, which indicates a likely preheating and controls strategy problem. At $10.00 per thousand pounds of steam, the cost impact of poor operations such as this can become very expensive.

Lessons Learned:

- ESPCs can be used to finance the purchase and installation of metering systems.
- It is cost-effective to combine the installation of meters for multiple utilities at the same time (as opposed to installing meters for one utility at a time).
- Correct design, specification, and installation are critical to the systems operating success.
- Costs for non-electric meters can be significantly higher than those for electric meters.

Costs for non-electric meters can be significantly higher than those for electric meters.

9.5 References

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Appendix A

Glossary of Common Terms

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Appendix A

Glossary of Common Terms

Advanced meters – Advanced meters are those that have the capability to measure and record interval data (at least hourly for electricity), and communicate the data to a remote location in a format that can be easily integrated into an advanced metering system. EPAct Section 103 requires at least daily data-collection capability.

Advanced metering system – A system that collects time-differentiated energy usage data from advanced meters via a network system on either an on-request or defined schedule basis. The system is capable of providing usage information on at least a daily basis and can support desired features and functionality related to energy-use management, procurement, and operations.

Air conditioning – The process of treating air so as to control its temperature, humidity, and cleanliness while distributing it to cool building space.

Application Service Provider (ASP) – Third-party entities that manage and distribute software-based services and solutions to customers across a wide-area network from a central data center.

Automated Meter Reading (AMR) – A form of advanced (or enhanced) metering that uses communications devices to communicate data from the meter to the meter data-management provider. AMR may be used to transmit simple energy-use data from the meter, or to transmit more complex measures of energy recorded in the meter, or to implement advanced functionality, such as outage detection or remote programming.

Average demand – The demand on, or the power output of, an electric system or any of its parts over an interval of time, determined by dividing the number of kilowatt hours by the number of hours in the interval.

Avoided cost – The total economic costs (consisting of the capital and operating costs to provide generation capacity and fuel, transmission, storage, distribution, and customer service) to serve end-use energy requirements using a given set of resources. These costs are referred to as “avoided” when an alternative set of resources is used to serve requirements. A better term for these costs would be “avoidable cost.” Avoided cost must be determined to assess the cost-effectiveness of potential supply-side and demand-side resources.

Base load – The minimum average electric load over a given period of time.

Baud rate – The rate of speed at which information is transmitted over communications lines; expressed in bits per second.

Billing demand – The demand for which a customer is billed. Since billing demand is based on the provisions of a rate schedule or contract, it does not necessarily equal the actual measured demand of the billing period.

Bits – A contraction of binary digits, the smallest unit of information in binary notation. A bit has the value of a zero (0) or a one (1). For example, the binary number 0110 consists of four bits.

British thermal unit (Btu) – A commonly used unit of energy, especially for fuels or heat. A kilowatt hour is equal to approximately 3412 Btu. Quantity of heat required to raise one pound of water by one degree Fahrenheit or the equivalent amount of energy generated by burning a kitchen match.

Building envelope – The exterior surfaces of a building, such as the roof, walls, windows, doors, etc., that are exposed to climatic conditions.

Capacity – The maximum quantity of electrical output for which a supply system or component is rated.

ccf – Hundred cubic feet.

cfm – Cubic feet per minute.

Coincident demand – Two or more demands that occur during the same time interval. Often used to express the demand level of subgroups of customers that occurs at the time of the electric system's overall maximum peak demand.

Constant dollars – Monetary value based on the purchasing power within the base year—inflationary impacts are not reflected in the value of the constant dollars.

Control – Any manual or automatic device designed to regulate the operation of a system or system component.

Cooling loads – The energy required to achieve the desired (space cooling) temperature level.

Cost avoidance – In regard to energy efficiency—the implementation of energy saving measures will result in a dollar savings which will offset any fuel price increase.

Cost-effective – The present value (PV) of the benefits of the potential resource under consideration over the planning period are greater than the PV of its costs. Cost-effectiveness is always measured relative to an alternative. Cost-effectiveness can be measured from a variety of perspectives, which vary in terms of the specific costs and benefits included in the calculation.

Damper – A valve or movable plate that is attached to a duct in order to regulate the flow of air or other gases.

Degree-days (cooling) – The difference between the average temperature of any given day and a base temperature when the median temperature of the given day is higher than the base temperature.

Degree-days (heating) – The difference between the average temperature on any given day and a base temperature when the median temperature of the given day is less than the base temperature. Often the base temperature selected is 65°F.

Dehumidification – The process of removing moisture.

Demand – The rate at which electricity is delivered by a system or part of a system, or to a load point or set of loads. It is measured in kilowatts, kilovolt amperes, or other suitable unit at a given instant or averaged over a designated period of time.

Dew point temperature – The temperature level in which the moisture in the air begins to condense.

Diversity – The diversity among customers' demands, which creates variations among the loads in distribution transformers, feeders, and substations at a given time. A load diversity is the difference between the sum of the maximum of two or more individual loads and the coincident or combined maximum load. It is usually measured in kilowatts.

Domestic hot water system (DHW) – A system designed to provide hot water for domestic needs—the energy required for a DHW system will vary according to building size, design, and human needs.

Dry bulb temperature – The temperature level as measured on a standard thermometer.

Duct work – A series of piping in which air is transferred from its source to the space that is to be conditioned. Ducts, which should be insulated to improve their efficiency, are generally made from fiberglass or galvanized metal.

Economizer cycle – Use of outside air without further mechanical cooling for space cooling when conditions are appropriate. Typically, this is accomplished by locking out the cooling coil.

Electric utility – A corporation, person, agency, authority, or other legal entity or instrumentality that owns and/or operates facilities within the United States, its territories, or Puerto Rico for the generation, transmission, distribution, or sale of electric energy primarily for use by the public and files forms listed in the Code of Federal Regulations, Title 18, Part 141. Facilities that qualify as co-generators or independent power producers under the *Public Utility Regulatory Policies Act* (PURPA) are not considered electric utilities. Electrical energy is usually measured in kilowatt-hours, whereas heat energy is usually measured in British thermal units.

Emission factor – The ratio of emissions to energy produced or fuel consumed, denominated in units of tons of emissions per unit of energy.

End-use – Useful work, such as light, heat, and cooling, which is produced by electricity or other forms of energy.

Energy – The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks.

Energy audit – Analysis of a facility's electricity and other energy usage, often including recommendations to alter the customer's electric demand or reduce energy usage. An audit usually is based on a visit by an energy analyst or engineer to the home, building, or manufacturing or agricultural facility.

Energy charge – The charge for electric service based upon the amount of electric energy (kWh) consumed and billed under an applicable rate schedule.

Energy cost liability – Estimated future energy expenditures without energy saving improvements.

Energy management system – A full or partially computerized system designed to monitor and control energy use in order to achieve optimal efficiency.

Energy use index (EUI) – Annual Btu/square foot energy use. The standard index used in most analyses to measure all fuel and energy used in a given building or group of buildings.

Ethernet – A specification for local communication networks that employs cable as a passive communication medium to interconnect different kinds of computers, information processing products, and office equipment at a local site.

Extensible Markup Language (XML) – Specification that allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data between applications and between organizations.

Firewall – A system designed to prevent unauthorized access to or from a private network. Firewalls can be implemented in both hardware and software, or a combination of both.

Gateway – In Local Area Networks (LANs), a computer system and its associated software that permit two networks using different protocols to communicate with each other. A gateway translates all protocol levels from physical layer up through applications layer and can be used to interconnect networks that differ in every detail.

Hourly Metering – A type of interval metering where the measurement or recording of customer use is collected in 6-minute intervals. The competitive metering model is based upon the implementation of hourly metering of customers or the application of load profiles, which average customer use over hourly periods.

HyperText Transfer Protocol – The underlying protocol used by the World Wide Web. HTTP defines how messages are formatted and transmitted and what action Web servers and browsers should take in response to various commands.

Incremental cost – The difference in costs between two alternatives, for example, between that of an efficient technology or measure and the standard technology.

Instantaneous peak demand – The demand at the instant of greatest load, usually determined from the readings of indicating meters or graphic meters.

Integrated demand – The summation of continuously varying instantaneous demands during a specified demand interval.

Interface – A device that allows communication between systems or ports of systems.

Interval metering – The measurement of customer energy use by fixed time periods or intervals. Typically, the interval time period is 15 minutes, but can vary according to the customer or transmission and distribution system needs. Today, interval metering is provided to commercial and industrial customers and some residential customers. In the future, in an unbundled environment, the residential market may require more frequent interval measurements.

IP address – Internet protocol address. See also **Ethernet**.

Kilowatt (kW) – One thousand watts.

Kilowatt-hour (kWh) – A standard unit of energy equivalent to a demand rate of 1,000 watts in one hour.

Levelized cost – The uniform annual cost that results in the same net present value over the planning horizon as the stream of actual annual average costs. An example of a levelized cost is a monthly mortgage payment.

Life-cycle costing (LCC) – The analytical process for estimating the total cost of a product or system over the life of the product or system, including the operational and maintenance costs.

Line losses – Kilowatt-hours and kilowatts lost in the transmission and distribution lines under specified conditions.

Load – The amount of electric power consumed at any specified point or points on a system. Load originates primarily in the power consuming equipment of the customers.

Load aggregation – Aggregation of energy consumption from facilities that are geographically separate from each other for purposes of acquiring and billing utility services.

Load duration curve – A graph showing a utility's hourly demand, sorted by size, as well as by the amount of time a given level of demand is exceeded during the year.

Load factor – The ratio of the average load in kilowatts supplied during a given period to the peak or maximum load in kilowatts occurring during that period. Load factor may be calculated for a customer, customer class, or the entire electric system.

Load leveling – A process in which the energy demand can be temporarily reduced during certain periods. Typical examples include the intermittent operation of certain electrical equipment and shutting off equipment when rooms or buildings are not in use.

Load management – The controlling, by rescheduling or direct curtailment, of the power demands of customers or groups of customers in order to reduce the total load that a utility must meet at times of peak demand. Load management strategies are designed to either reduce or shift demand from on-peak to off-peak, while conservation strategies reduce usage over larger multi-hour periods. Load management may take the form of normal or emergency procedures. Utilities often encourage load management by offering customers a choice of service options with varying price incentives.

Local Area Network (LAN) – Computer network that spans a relatively small area megawatt (MW)—One million watts.

Mcf – Thousand cubic feet.

Modbus® Protocol – A messaging structure developed by Modicon in 1979, used to establish master-slave/client-server communication between intelligent devices. It is a de facto standard, truly open, and the most widely used network protocol currently available.

Modem – Modulator-demodulator. A device or program that enables a computer to transmit data over telephone lines.

Multipoint communications – A method of communication in which a single device can communicate to multiple devices.

MV-90 – The utility industry de facto standard for data collection and storage systems. This system was developed so that meters from different vendors could be read and the data stored in a consistent manner.

NEMA Standards – Property characteristics adopted as standard by the National Electrical Manufacturers Association.

Net present value (NPV) – The value of future energy savings—less all project construction and operating costs, discounted to present value.

Network – A group of computing devices that are connected to each other by communications lines to share information and resources.

Nominal levelized cost – The uniform cost of electricity, in mixed current dollars, for which the present value of the cost of electricity produced over the life of the plant is equal to the present value of the costs of the plant.

Non-volatile memory – Memory that retains its contents when power is lost peak demand; the maximum load during a specified period of time.

Off-peak energy – Electricity supplied during periods of relatively low system demand.

Peak demand – The maximum rate of electricity consumption, expressed in gigawatts. May be expressed for groups of electricity users or the whole system, and by season (summer or winter) or annually. See **demand**. Also called peak load.

Peak load – The maximum anticipated demand for any given system.

Peaking unit, or peaker – A generating station that is normally operated to provide power during maximum load periods.

Planning period – The time period over which the utility Integrated Resource Planning (IRP) analysis is performed.

Potential resources – Resources, either supply-side or demand-side, which are either currently commercially available, feasible, or are expected to be commercially available within the planning period.

Power Line Carrier (PLC) – Communication system that transmits data between devices over power lines.

Present value – The value of a cost or stream of yearly costs that have been discounted to reflect the fact that future benefits or expenditures are worth less than current benefits or expenditures. Also called present worth.

Programmable Logic Controller (PLC) – A solid-state control system that has a user programmable memory for storage instruction to implement specific functions such as input/output (I/O) control logic, timing, counting, arithmetic, and data manipulation.

Protocol – A standardized procedure for establishing a communications link between devices and that is based on such elements as word structure or word length.

Radio frequency (RF) – Refers to alternating current (AC) having characteristics such that, if the current is input to an antenna, an electromagnetic (EM) field is generated suitable for wireless broadcasting and/or communications.

Real levelized cost – The uniform cost of electricity, in constant dollars, for which the present value of the electricity produced equals the present value of the costs of the plant. See also the levelization formulae following this glossary.

Real-time metering – Metering that records consumer use in the same time frame as pricing changes in the market, typically hourly or more frequently.

Real-time pricing (RTP) – The instantaneous pricing of electricity based on the cost of electricity available for use at the time the electricity is demanded by the customer.

Relative humidity (RH) – The percentage of moisture contained in the air compared to saturation.

Retrofit – Energy saving improvements to a building structure or any of its energized systems involving modification of that structure or system.

Return on investment (ROI) – The discount rate which, when used to discount all present and future project costs and savings, brings the net present value to zero.

RS-485 Serial Communications Bus – An Electronics Industry Association (ETA) standard for multipoint communications. RS-485 is similar to RS-422 but can support more nodes per line because it uses lower-impedance drivers and receivers.

Server – A computer or device on a network that manages network resources. For example, a file server is a computer and storage device dedicated to storing files.

Transmission Control Protocol/Internet Protocol (TCP/IP) – The suite of communications protocols used to connect hosts on the Internet. TCP/IP uses several protocols, the two main ones being TCP and IP. TCP/IP is built into the UNIX operating system and is used by the Internet, making it the de facto standard for transmitting data over networks.

therm – Equals 100,000 Btus.

Time of use – The pricing of electricity based on the estimated cost of electricity during a particular time block.

Tons of refrigeration – A standard for identifying cooling capacity. One ton of refrigeration is equal to 12,000 Btu/hour of cooling.

Utility discount rate – A rate that reflects the utility's weighted cost of capital. Pre-tax or, more commonly, after tax.

Valley filling – The building of off-peak loads. An example of valley filling technology is thermal storage (water heating and/or space heating or cooling) that increases nighttime loads and reduces peak period loads. Valley filling may be desired in periods when the long-run incremental cost of supply is less than the average price of electricity. (Adding off-peak load under those circumstances decreases the average price.)

Variable operating and maintenance (O&M) costs – The additional cost per kWh of electricity produced that goes toward operation and maintenance of the plant. These costs vary with the output of the plant and are expressed in cents per kWh of electricity produced.

Watt – The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor.

Watt-hour – The total amount of energy used in one hour by a device that requires one watt of power for continuous operation. Electric energy is commonly sold by the kilowatt-hour (1,000 W).

Appendix B

Energy Policy Act Requirements

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Appendix B

Energy Policy Act Requirements

SEC. 103. ENERGY USE MEASUREMENT AND ACCOUNTABILITY.

Section 543 of the National Energy Conservation Policy Act (42 U.S.C. 8253) is further amended by adding at the end of the following.

"(e) METERING OF ENERGY USE.—

"(1) DEADLINE.—By October 1, 2012, in accordance with guidelines established by the Secretary under paragraph (2), all Federal buildings shall, for the purposes of efficient use of energy and reduction in the cost of electricity used in such buildings, be metered. Each agency shall use, to the maximum extent practicable, advanced meters or advanced metering devices that provide data at least daily and that measure at least hourly consumption of electricity in the Federal buildings of the agency. Such data shall be incorporated into existing Federal energy tracking systems and made available to Federal facility managers.

"(2) GUIDELINES.—

"(A) IN GENERAL.—Not later than 180 days after the date of enactment of this subsection, the Secretary, in consultation with the Department of Defense, the General Services Administration, representatives from the metering industry, utility industry, energy services industry, energy efficiency industry, energy efficiency advocacy organizations, national laboratories, universities, and Federal facility managers, shall establish guidelines for agencies to carry out paragraph (1).

"(B) REQUIREMENTS FOR GUIDELINES.—The guidelines shall—

"(i) take into consideration—

"(I) the cost of metering and the reduced cost of operation and maintenance expected to result from metering;

"(II) the extent to which metering is expected to result in increased potential for energy management, increased potential for energy savings and energy efficiency improvement, and cost and energy savings due to utility contract aggregation; and "(III) the measurement and verification protocols of the Department of Energy;

"(ii) include recommendations concerning the amount of funds and the number of trained personnel necessary to gather and use the metering information to track and reduce energy use;

“(iii) establish priorities for types and locations of buildings to be metered based on cost-effectiveness and a schedule of one or more dates, not later than 1 year after the date of issuance of the guidelines, on which the requirements specified in paragraph (1) shall take effect; and

“(iv) establish exclusions from the requirements specified in paragraph (1) based on the de minimis quantity of energy use of a Federal building, industrial process, or structure.

“(3) PLAN.—Not later than 6 months after the date guidelines are established under paragraph (2), in a report submitted by the agency under section 548(a), each agency shall submit to the Secretary a plan describing how the agency will implement the requirements of paragraph (1), including (A) how the agency will designate personnel primarily responsible for achieving the requirements and (B) demonstration by the agency, complete with documentation, of any finding that advanced meters or advanced metering devices, as defined in paragraph (1), are not practicable.

Appendix C

Metering Codes and Standards

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Appendix C

Metering Codes and Standards

Codes and standards applicable to metering equipment and installation are generally governed and promulgated by national organizations and enforced by local entities such as building code officials.

Because different parts of the country have traditionally referenced different code organizations for specific codes, the authors of this guide recommend contacting local building code officers (electric, natural gas, and plumbing inspectors) prior to initiating any meter selection or installation project.

Below are presented some of the more common standards as they apply to the major metering categories.

Electric Meters and Installation Codes and Standards

All electric meters installed must comply with the National Electric Code (NEC) as found in the National Fire Protection Association (NFPA) 70. Additional standards from the American National Standards Institute (ANSI) are provided below.

American National Standards Institute (ANSI) C12 metering standards:

- ANSI C12.1 – American National Standard Code for Electricity Metering
- ANSI C12.4 – American National Standard for Mechanical Demand Registers
- ANSI C12.5 – American National Standard for Thermal Demand Meters
- ANSI C12.6 – American National Standard for Marking and Arrangement of Terminals

Self-Contained A-Base Watt-Hour Meters

- ANSI C12.9 – American National Standard for Test Switches for Transformer-Rated Meters
- ANSI C12.10 – American National Standard for Electromechanical Watt-Hour Meters
- ANSI C12.11 – American National Standard for Instrument Transformers for Revenue Metering, 10 kV BIL Through 350 kV BIL
- ANSI C12.13 – American National Standard for Electronic Time-of–Use Registers for Electricity Meters
- ANSI C12.14 – American National Standard for Magnetic Tape Pulse Recorders for Electricity Meters
- ANSI C12.15 – American National Standard for Solid-State Demand Registers

Electromechanical Watt-Hour Meters

- ANSI C12.16 – American National Standard for Solid-State Electricity Meters

- ANSI C12.17 – American National Standard for Cartridge-Type Solid-State Pulse Recorders

The Institute of Electrical and Electronics Engineers (IEEE) has standards related to electromagnetic immunity including:

- IEEE C.37-90.1-1989 – IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems (ANSI). All inputs tested, except for the network communications port.

ANSI is a member of the IEC (International Electrotechnical Commission), which has adopted the following standards related to metering:

- IEC1000-4-2 (EN61000-4-2/IEC801-2) – Electrostatic Discharge (B)
- IEC1000-4-3 (EN61000-4-3/IEC801-3) – Radiated EM Field Immunity (A)
- IEC1000-4-4 (EN61000-4-4/IEC801-4) – Electric Fast Transient (B)
- IEC1000-4-5 (EN61000-4-5/IEC801-5) – Surge Immunity (B). Certified by American Electric Power (AEP)
- IEC1000-4-6 (EN61000-4-6/IEC801-6) – Conducted Immunity
- IEC 60687 0.2S, section 4.6.1, 4.6.2, 4.6.3.

The Federal Communications Commission (FCC) also regulates electromagnetic emission:

- FCC Part 15 Subpart B, Class A: Class A Digital Device, Radiated Emissions. d. IEC Compliance.

Other organizations might impose local requirements. For example, the California Independent System Operator (ISO) has standards and protocols for installing, reading, and maintaining meters on the system including:

- ISO MTR1-96 – Engineering Specifications for Poly-Phase Solid-State Electricity Meters for use on the ISO Grid.

Many of the standards addressed above are very specific and not always applicable. Their presentation highlights the depth to which metering and communication standards apply. As mentioned, the best resource may well be a local building code official for these and other code/standard issues and questions.

Natural Gas Meter and Installation Codes and Standards

All natural gas meters installed must comply with the National Fuel Gas Code as found in the as found in the National Fire Protection Association (NFPA) 54. Additional codes and standards may apply as issued by state and local code authorities. The best resource for complete and up-to-date code information may well be a local building code official.

Water Meter and Installation Codes and Standards

Water meters and installation are usually governed by the Uniform Plumbing Code but will often be superseded/amended by local ordinances specific to the region. The best resource for complete and up-to-date code information will be a local building code official.

Appendix D

Suggestions for Additions or Revisions

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Appendix D

Suggestions for Additions or Revisions

This guide is a living document, open to periodic updates and improvement. Readers are encouraged to submit suggestions for additions, deletions, corrections, or where to go for other resources.

In addition, we are interested in what has worked at your federal site. We want to find other case studies and documentation of your successes.

Please send or fax your information to:

Greg Sullivan
Pacific Northwest National Laboratory (PNNL)
P.O. Box 999, MS K6-10
Richland, WA 99352
Fax: (509) 372-4370

Additional material to include (please be specific): ______________________________

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Additional references/resources: ______________________________

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Case study material (feel free to attach additional sheets): ______________________________

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EERE Information Center
1-877-EERE-INF or 1-877-337-3463
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U.S. Department of Energy
Energy Efficiency
and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio